CROPS AND SOILS RESEARCH 1976

DEPARTMENT OF AGRONOMY
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INTRODUCTION

Research Program in the Department of Agronomy

This report gives the research in progress in the Department of Agronomy. The research program in the Department includes the development of improved crop varieties and improved soil and crop management practices that result in more efficient crop production. Considerable emphasis is also given to research on soil and water conservation, soil and water use, soil-water pollution, air pollution and the disposal of waste materials.

The wide range of soils and 2.0 million acres of agronomic crops (corn, soybeans, tobacco, small grain, turfgrasses, hay, and pasture) grown in the state with a value of approximately 336 million dollars emphasize the size and importance of the research program in agronomy. To solve crops and soils problems research work is conducted at University Laboratories, on the outlying Experiment Station Farms, and cooperatively with farmers, golf course superintendents, and others throughout the state. The help and cooperation received from the many people in the state in carrying out our research program is greatly appreciated.

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Chairman, Department of Agronomy

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TABLE OF CONTENTS

Page

Introduction . . . . . .

Crops and Soils Research Reports

Comparison of Two Ureas and Ammonium Nitrate in Grain Production
F. A. Abbruscato and J. H. Axley 1

Use of Sewage Sludge Compost for the Establishment of Turfgrass Sod
J. S. Angle, D. C. Wolf, and J. R. Hall III 7

Performance of Maryland Tobacco Varieties and Breeding Lines, 1975
M. K. Aycock, Jr. 13

Breeding for Disease Resistance in Maryland Tobacco, 1976
M. K. Aycock, Jr. 16

Performance of Breeding Lines in the Preliminary Variety Test, 1976
M. K. Aycock, Jr. 21

No-Tillage vs. Conventional Tillage Corn Fertilization, I. Influence of Nitrogen Rate
V. A. Bandel, C. M. Reynolds, and C. E. Rivard 24

No-Tillage vs. Conventional Tillage Corn Fertilization, II. Influence of Nitrogen Source
V. A. Bandel, C. E. Rivard, and F. R. Mulford 38

No-Tillage vs. Conventional Tillage Corn Fertilization, III. Fertilizer Placement and Micronutrients on Poorly Drained Soils
V. A. Bandel, C. E. Rivard, and F. R. Mulford 55

Effect of Liquid Nitrogen Applications on Soil pH
G. W. Burt 58

Field Evaluation of HOE-29152 Pre and Post Emergence on Johnsongrass in Soybeans
G. W. Burt 61

The Influence of Variety, Stage of Growth and Surfactant on HOE-29152 Injury to Soybeans
G. W. Burt 63

Alfalfa Variety and Strain Tests
N. A. Clark and J. H. McNemar 69

Corn Silage Variety and Strain Test
N. A. Clark and J. H. McNemar 73

Effects of Sewage Sludge and Fertilizer Application on the Yields and Chemical Composition of Corn and Soybeans
A. M. Decker, R. L. Chaney and D. C. Wolf 76

Page

Pasture Improvement with Sod-Seeding
A. M. Decker, J. H. Vandersall, N. A. Clark, and D. J. Undersander . . 86

Extractable Zinc Levels in an Anaerobic Soil Amended with Sludge
E. A. Hartzell and D. C. Wolf 92

Tee Turf Research
D. T. Hawes 99

Breeding of New Small Grain Varieties
J. W. Johnson 105

Performance of Barley Varieties and Breeding Lines in Maryland, 1976
J. W. Johnson 107

Performance of Wheat Varieties and Breeding Lines in Maryland, 1976
J. W. Johnson 110

Performance of Soybean Advanced Breeding Lines in Maryland
W. J. Kenworthy 113

Performance of Soybean Varieties and Breeding Lines in Maryland, 1976
W. J. Kenworthy 117

Extractability and Uptake by Corn of High Concentrations of Cd, Cu, Ni and Zn applied to Different Soil Materials at Two pH Regimes
R. F. Korcak and D. S. Fanning 122

The Importance of Indigenous Soil Mn in Soil Heavy Metal Studies
R. F. Korcak and D. S. Fanning 139

Respiration Rate of Soil Amended with Salt Sprayed Soybean Residue
G. McClung and D. C. Wolf 148

Influence of Montmorillonite, Micronutrients, pH and Nitrogen Source on the Growth of Penicillium frequentans
R. W. McCormick and D. C. Wolf 153

Irrigation with Maryland Tobacco, 1976
C. G. McKee 159

Low Plant Population Studies with Maryland Tobacco
C. G. McKee 162

The Response of Alfalfa to Irrigation Fertility and Cutting Management
J. H. McNemar and N. A. Clark 166

Influence of Nitrogen Sources on the Response of Maryland Tobacco to Chloride Fertilization
C. L. Mulchi and J. A. Armbruster 171

Page

Effects of Simulated Salt Drift on Maryland Tobacco Using Brackish Water from Cooling Towers at Chalk Point
C. L. Mulchi, W. W. Newcomb and J. A. Armbruster 177

Effects of Simulated Salt Drift on Corn and Soybeans Using Brackish Water from the Cooling Towers at Chalk Point
C. L. Mulchi and J. A. Armbruster 185

Response of Maryland Tobacco to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers
C. L. Mulchi and J. A. Armbruster 191

Response of Corn and Soybeans to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers
C. L. Mulchi and J. A. Armbruster 200

Nitrogen Mineralization in a Manure Amended Evesboro Sandy Loam
D. K. Patten and D. C. Wolf 208

Zinc Uptake from Flooded Soils
V. Pavanasasivam and J. H. Axley 212

Composting Organic Wastes by Suction Aeration Techniques
M. A. Ramirez, J. E. Foss and J. C. Patterson 216

Chemical and Mineralogical Examination of Serpentine and Associated Soils in Maryland
M. C. Rabenhorst and J. E. Foss 226

Corn Production and Heavy Metal Content as Influenced by Sewage Sludge Application and Soil Temperature
C. C. Sheaffer, A. M. Decker, and R. L. Chaney 231

Influence of Organic Animal Waste on the Leaching of Calcium from Soil
P. A. Snow and J. H. Axley 242

Mapping of Highly Man Influenced Soils in Washington, D. C.
C. E. Stein, D. S. Fanning and J. C. Patterson 248

Comparison of Two Ureas and Ammonium Nitrate In Grain Production

F. A. Abbruscato and J. H. Axley

Purpose and Objectives

Urea, according to fertilizer manufacturers, is the most inexpensive solid form of nitrogen fertilizer when application costs are included. For this reason they are gearing up to sell urea. The form of urea they have in mind is a larger, heavier particle than previously manufactured. This granulated urea is less likely to segregate in storage or during spreading when blended with potassium chloride, concentrated super phosphate or di- or mono-ammonium phosphates. It is larger in size than the old prilled urea. It is also coated with urea formaldehyde which gives the particle more favorable handling characteristics.

The objectives of this study were:

1. To compare rates of application of the old type prilled urea, the new larger and more dense granulated urea and ammonium nitrate on small grain yields.
2. To study yield and stand as influenced by fertilizer placement in relation to the seed.
3. To compare fall drilling of these fertilizers with early spring broadcasting on an established stand.

Procedure

Winter wheat (variety Arthur 71) was planted in late October, 1975 at two locations in Maryland. Three sources of nitrogen were used: NH_4NO_3 (35% N), granulated (new) urea (46% N), and prilled (old) urea (45% N). Fertilizer was drilled with the seed at an equivalent rates of 15, 30, 60, and 120 pounds of nitrogen per acre. A second phase of this study involved fall seedings that were top-dressed in the spring with the nitrogen fertilizers.

In a third experiment with Potomac wheat, the nitrogen fertilizers were broadcasted in the spring as described in the second phase.

Results

The results in Table 1 show that nitrogen from the various sources (urea or ammonium nitrate) gave similar yields when 30 lbs N/A or less was drilled with the seed.

When 60 and 120 lb/A of nitrogen as urea were drilled with the seed, yields were drastically reduced. Reduced yields were due to a significant reduction in stand at the higher urea rates due to ammonia injury as a result of close contact of the fertilizer with the seed. Ammonium nitrate fertilizer did not seem to injure the seed because it releases very little ammonia. This was suggested by wheat yields which were highest when 120 lbs of nitrogen as ammonium nitrate was drilled with the seed (Table 1).

Nitrogen applied at rates of 60 and 120 lbs per acre may cause lodging in some varieties. County agents should be consulted when such quantities are considered.

When nitrogen was broadcast on established stands of wheat (Tables 2 and 3), the prilled form of urea and ammonium nitrate performed equally well. The new granulated form of urea appeared to be slightly inferior to prilled urea and ammonium nitrate.

Summary

Urea applied at rates up to 30 lbs N/A (65 lbs of urea) drilled with the wheat and were equally as effective as ammonium nitrate.

Urea at rates greater than 60 lbs of nitrogen (130 lbs of urea) applied with the drill at seeding reduced yields significantly.

Ammonium nitrate did not exhibit seeding injury at rates of 120 lbs of nitrogen.

Broadcasting urea in the early spring after stands are established reduces the possibility of urea injury as compared to drilling with the seed and results in higher yields.

Table I. Influence of Nitrogen fertilizers drilled with Arthur wheat on grain yields. Fall 1976.

Nitrogen Application lbs/A	Type of Nitrogen Fertilizer	Beltsville Bu/A	Poplar Hill Bu/A
15	Urea (45%)	38.1*	11.6 **
15	Urea (46%)	38.9	19.8
15	NH_4NO_3	38.7	20.3
30	Urea (45%)	35.8	18.4
30	Urea (46%)	36.8	21.9
30	NH_4NO_3	36.4	20.3
60	Urea (45%)	32.5	17.3
60	Urea (46%)	32.8	14.8
60	NH_4NO_3	35.5	24.7
120	Urea (45%)	16.9	5.6
120	Urea (46%)	23.7	8.1
120	NH_4NO_3	49.0	28.6

* L.S.D. at 5% probability level = 7.2 Bu/A

** L.S.D. at 5% probability level = 5.1 Bu/A

Table 2. Yields of Arthur wheat as influenced by variable rates of urea and ammonium nitrate broadcast in early March. 1976.

Nitrogen Application lbs/A	Type of Nitrogen Fertilizer	Yield ** Bu/A
15	Urea (45%)	41.2 *
15	Urea (46%)	34.2
15	NH_4NO_3	41.7
30	Urea (45%)	39.7
30	Urea (46%)	37.9
30	NH_4NO_3	40.6
60	Urea (45%)	45.4
60	Urea (46%)	41.7
60	NH_4NO_3	45.5
120	Urea (45%)	49.8
120	Urea (46%)	49.9
120	NH_4NO_3	51.9

* L.S.D. at 5% probability level = 5.5 Bu/A

** Beltsville, Md. 1976

Table 3. Yields of Potomac wheat as influenced by variable rates of urea and ammonium nitrate broadcast in early March. 1976.

Nitrogen Application lbs/A	Nitrogen Source lbs/A of N	Yield ** Bu/A
30	Urea (46%)	64.8 *
30	Urea (45%)	65.9
30	NH_4NO_3	62.9
60	Urea (46%)	67.5
60	Urea (45%)	69.8
60	NH_4NO_3	69.7
120	Urea (46%)	69.6
120	Urea (45%)	69.9
120	NH_4NO_3	70.5

* No statistical analysis to date

** Poplar Hill, Md. 1977

Use of Sewage Sludge Compost for the Establishment of Turfgrass Sod

J. S. Angle, D. C. Wolf, and J. R. Hall III

Purpose and Objectives

The use of sewage sludge compost as a soil amendment presents a method of sewage sludge disposal while simultaneously providing a valuable product which can be used to improve both the chemical and physical properties of most soils. Sewage sludge compost is particularly well suited as a turfgrass fertilizer. Maryland's large acreage of turfgrass located near the metropolitan areas is therefore, of particular importance when evaluating areas for sewage sludge disposal. The use of compost for the establishment of turfgrass sod in metropolitan areas has the potential for being both an economical and practical method of sludge utilization. The purpose of this study was to evaluate the use of sewage sludge compost for the establishment of turfgrass sod.

Procedure

The sewage sludge compost used in this experiment was provided by the U.S. Department of Agriculture, Agricultural Research Service, Biological Waste Management and Soil Nitrogen Laboratory, Beltsville, Maryland, and the Maryland Environmental Service, Annapolis, Maryland. The percent moisture and volatile material of the compost was 40% and 30%, respectively. The concentration of macro-nutrients in the compost was 1.68, 1.98, and 0.55% for N. P. and K, respectively. The concentration of some heavy metals in the compost was 13, 141, 01260, and 01580 ug/g for Cd, Ni, Cu, and Zn, respectively. The compost was applied to the soil at rates of 0, 90, 180, 360, and 720 mT/ha and incorporated to a depth of 15 cm.

The soil used was a Sassafras sandy loam. Prior to compost addition, the soil had a cation exchange capacity of 5.4 meq/100 g, pH 5.1 and the percent sand, silt, clay and organic matter was 60, 35, 5, and 1.33, respectively.

The two turfgrass sods used in this experiment were (1) commercially available Kentucky bluegrass-red fescue (Poa pratensis L.) which consisted of a mixture of 30% Merion, 30% South Dakota Certified, and 30% Fylking bluegrass, plus 10% red fescue (Festuca rubra L. 'Pennlawn'), and (2) 90% Kentucky-31 tall fescue (Festuca arundinaceae Schreb) and 10% South Dakota Certified Kentucky bluegrass. The sodding date was November 20, 1975, and the sod was maintained at a height of 5.7 cm by mowing as required. Clippings were collected during mowing, dried to a constant weight, and used to determine the growth rate of the turfgrasses. Twice monthly the color and quality of the turfgrasses were determined by rating on a scale of 0 to 9 with a value of 6 being the acceptable and 9 being the highest attainable value. During March and September, 1976, clipping samples were also analyzed for total nitrogen and phosphorus.

Results

Turfgrass color and quality data are presented in Table 1. The results indicate that the addition of compost increased the color rating for Kentucky bluegrass at rates up to and including 360 mT/ha. The Kentucky-31 tall fescue exhibited increased color ratings throughout the compost rates tested and had highest ratings at the 720 mT/ha rate. The quality ratings also showed that the addition of compost resulted in higher quality turfgrass. Both turfgrasses were rated highest at the 720 mT/ha of compost treatment. Some or all of the increase in color and quality most likely resulted from an increase in available nitrogen supplied by the compost. The soil water holding capacity, temperature, and bulk density were favorably altered by the addition of compost and these factors may also have had an influence on the color and quality ratings of the turfgrasses.

Growth rates of Kentucky bluegrass and Kentucky-31 tall fescue were generally increased by the addition of compost (Table 2). Maximum growth occurred for both grasses when 720 mT/ha of compost had been incorporated into the soil.

Varying growth rates over time were attributed to changes in the weather. During favorable growing conditions, the turfgrasses responded to the additional nitrogen more readily than during adverse weather conditions.

Foliar nitrogen and phosphorus levels of the two turfgrasses sampled 100 days after sod establishment are presented in Table 3. Results indicate that the addition of compost to the soil generally increased the phosphorus content of both turfgrasses. Kentucky-31 tall fuscue exhibited increased nitrogen content with increased compost addition. Kentucky bluegrass did not follow this trend.

Summary

Preliminary results from these experiments indicate that the addition of sewage sludge compost at rates up to 720 mT/ha for the establishment of Kentucky bluegrass and Kentucky-31 tall fescue sod resulted in increased color, quality and growth rate. Results indicate that use of sewage sludge compost has the potential to be a useful turfgrass management practice.

TABLE 1. Mean color and quality ratings of Kentucky bluegrass and Kentucky-31 tall fescue sod on a Sassafras sandy loam soil amended with five rates of composted sewage sludge. The data were collected from March 3, 1976, to September 30, 1976.

Turfgrass	Compost Rate (mT/ha) 0	90	180	360	720
	Color Rating				
Bluegrass	6.8 ± 0.9[1/]	7.3 ± 0.7	7.5 ± 1.0	8.0 ± 0.8	7.9 ± 1.1
Tall Fescue	6.9 ± 0.9	7.3 ± 0.9	7.7 ± 1.1	7.7 ± 0.9	8.3 ± 0.7
	Quality Rating				
Bluegrass	6.5 ± 0.8	7.5 ± 1.0	7.6 ± 0.6	7.9 ± 0.5	8.3 ± 0.9
Tall Fescue	6.9 ± 0.9	7.4 ± 0.8	7.5 ± 0.5	7.7 ± 1.0	8.3 ± 0.6

[1/] All values are presented as the mean ± one standard deviation.

TABLE 2. Growth rate of Kentucky bluegrass and Kentucky-31 tall fescue sod on soil amended with five rates of composted sewage sludge and sampled at various times.

Date	Turfgrass	Compost rate (mT/ha)				
		0	90	180	360	720
		g/m^2 day				
5-6-76	bluegrass	2.75	2.62	3.44	3.58	3.07
	tall fescue	2.60	3.22	3.91	4.07	4.64
6-14-76	bluegrass	1.37	2.17	4.21	4.07	4.97
	tall fescue	1.99	2.46	4.79	5.39	5.76
7-13-76	bluegrass	3.07	5.45	4.51	6.01	7.20
	tall fescue	4.53	6.54	5.29	5.78	6.81
8-13-76	bluegrass	1.97	3.31	4.07	3.52	4.46
	tall fescue	2.89	2.19	2.74	3.13	3.34
9-10-76	bluegrass	1.12	1.18	1.64	1.22	1.33
	tall fescue	1.64	2.03	2.88	2.58	2.16
10-18-76	bluegrass	1.46	1.78	2.20	2.63	2.34
	tall fescue	1.98	2.47	3.22	3.14	3.77

TABLE 3. Nitrogen and phosphorus analysis of bluegrass and tall fescue samples collected 100 days after sod establishment on soils amended with five levels of composted sewage sludge. 1/

Compost Rate (mT/ha)	Turfgrass	Nitrogen	Phosphorus
		%	
0	tall fescue	3.95 ± .20	.40 ± .03
	bluegrass	4.24 ± .77	.36 ± .00
90	tall fescue	3.73 ± .28	.39 ± .03
	bluegrass	3.55 ± .07	.38 ± .03
180	tall fescue	4.32 ± 1.18	.43 ± .04
	bluegrass	4.14 ± .67	.48 ± .06
360	tall fescue	4.46 ± 1.27	.41 ± .05
	bluegrass	4.00 ± .24	.43 ± .03
720	tall fescue	5.07 ± .82	.45 ± .07
	bluegrass	4.24 ± .10	.46 ± .07

1/ Values are presented as the mean ± one standard deviation.

Performance of Maryland Tobacco Varieties and Breeding Lines, 1975

M. K. Aycock, Jr.
Department of Agronomy

Purpose and Objectives

The Official Variety Test is the final phase of the breeding program and has three main objectives: (1) To obtain additional information on the varieties presently being grown by the majority of the tobacco farmers, (2) to evaluate advanced breeding lines which appear to have potential as a new variety, and (3) to provide a guide to Maryland tobacco farmers for use in choosing a variety to produce their best crop.

Procedures

Each year the variety tests are conducted at three locations with varying soil types. The tests are located on a Monmouth fine sandy loam at Upper Marlboro, Galestown loamy sand at Davidsonville, and Beltsville silt loam at Dentsville.

The 1975 test which is included in the present report contained five varieties and ten breeding lines. Seven breeding lines in the test were developed by the USDA at Beltsville under the direction of H. A. Skoog, and two breeding lines were Agricultural Experiment Station entries, A19 and A31 from the Agronomy Department.

Four replications of a randomized complete block design were used at each location. Each plot consisted of one row of 23 competitive plants. The plots were three feet apart and plants spaced two feet apart in the plot. Fifteen competitive plants per plot were cut at harvest.

The various agronomic and chemical characteristics measured and methods of data collection have been outlined by Aycock *et al.* (1).

Results

The average performance of the varieties and breeding lines compared at three locations in 1975 is shown in Table 1. Md. 64 was the highest yielding variety with 1652 pounds of cured leaf per acre. Md. 872 and Md. 201 produced slightly less cured leaf per acre than Md. 64, but these two new varieties had a higher dollar per hundredweight value than Md. 64. Md. 609 was the best quality variety with an average of $91.76 per hundredweight. Several breeding lines compared very favorably with the best varieties. A19 and J-74-343 were the highest yielding breeding lines. The value of these two breeding lines also compared very favorably with the standard varieties. The varieties and breeding lines ranged from 1.04% (J-74-224) to 1.73% (J-74-304) for total alkaloids. Significant variation was noted also among most of the other agronomic, physical, and chemical traits measured. Several breeding lines compared very favorably with the standard varieties for these traits.

Summary

The variety testing program was conducted at three locations in 1975. Several breeding lines with multiple disease resistance appear to have a real potential as new varieties.

Acknowledgment

The computer time for the statistical analyses was made available through the facilities of the Computer Science Center of the University of Maryland.

Literature Cited

1. Aycock, M. K., Jr., H. A. Skoog, O. D. Morgan, C. G. McKee, J. H. Hoyert and C. L. Mulchi. 1975. Performance of Maryland tobacco varieties and breeding lines, 1973 and 1974, Maryland Agr. Exp. Sta. MP 884.

Table 1. Performance of Maryland tobacco varieties and breeding lines at three locations, 1975.

Variety or breeding line	Yield per acre (lbs.)	Value		Plant height (in.)	Leaves per plant	Internode length (in.)	Days to flower	Total alkaloids (%)	Total nitrogen (%)	Duration of burn (sec./leaf)	Filling capacity (cc/g)
		$/A	$/cwt								
Md. 10	1348	1228	91.13	32.1	18.4	1.75	54.0	1.44	1.91	18.42	6.88
Md. 609	1350	1238	91.76	32.8	18.0	1.82	54.5	1.31	2.13	22.35	7.08
Md. 64	1652	1456	88.10	31.2	20.3	1.53	55.2	1.32	2.01	18.84	6.44
Md. 872	1521	1388	91.19	32.8	17.8	1.84	52.9	1.29	2.07	18.08	7.04
Md. 201	1484	1334	89.92	31.7	19.9	1.57	57.4	1.34	1.86	18.36	6.62
A19	1556	1410	90.70	35.4	18.5	1.92	50.0	1.18	1.89	22.63	6.69
A31	1297	1180	91.04	35.7	19.0	1.88	55.0	1.31	1.96	17.76	6.87
J-74-1	1515	1377	90.90	32.3	21.7	1.49	56.6	1.58	1.87	18.15	6.89
J-74-224	1504	1320	87.59	35.1	19.7	1.78	53.5	1.04	1.97	21.97	6.82
J-74-301	1521	1394	91.60	32.3	18.2	1.77	57.9	1.72	2.02	18.26	6.65
J-74-304	1540	1400	90.87	33.6	19.3	1.73	56.1	1.73	2.04	17.90	6.66
J-74-314	1518	1363	89.75	34.2	18.4	1.86	50.1	1.30	2.08	21.62	6.82
J-74-315	1439	1288	89.42	33.5	17.2	1.95	51.8	1.15	1.93	21.45	6.96
J-74-343	1547	1408	90.90	32.4	20.4	1.58	52.8	1.30	1.94	20.29	6.81
J-74-339	1540	1386	89.82	33.8	19.8	1.71	52.9	1.51	1.84	17.99	7.02
Mean	1489	1345	90.31	33.2	19.1	1.75	54.0	1.37	1.97	19.60	6.82
L.S.D. (0.05)	155	144	1.45	N.S.	1.4	0.11	2.8	0.30	0.15	N.S.	N.S.
(0.01)	209	N.S.	1.96	N.S.	1.9	0.14	3.8	0.40	0.20	N.S.	N.S.
C.V. (%)	10.4	11.4	1.8	6.8	6.2	5.8	2.8	22.5	10.5	12.2	6.1

Breeding for Disease Resistance in Maryland Tobacco, 1976

M. K. Aycock, Jr.
Department of Agronomy

Purpose and Objectives

A number of diseases attack tobacco grown in southern Maryland; therefore, a large part of the breeding program at the University of Maryland is concerned with disease resistance. In past years the tobacco mosaic virus was one of the most destructive diseases and until 1969, none of the varieties being grown had mosaic resistance (3). At the present time three mosaic resistant varieties (1, 3, 4) and two black shank resistant varieties (2) are available for production. Other diseases which cause some loss in Maryland tobacco each year are black root rot (Thielaviopsis basicola), wildfire (Pseudomonas tabaci), black shank (Phytophthora parasitica var. nicotianae), and fusarium wilt (Fusarium oxysporum var. nicotianae). At present the tobacco breeding program is concerned with developing varieties with resistance to three diseases -- tobacco mosaic, black shank, and fusarium wilt.

Procedures

Breeding for Black Shank Resistance. The sources of resistance to black shank presently being used are from Md. 59 and Md. 609, two varieties released in 1965; and L8, a burley tobacco variety. Md. 59 and Md. 609 were developed by Dr. O. D. Morgan, and the source of black shank resistance was from Florida 301. L8 contains resistance from Nicotiana longiflora.

During the winter of 1976-77, a modification of a black shank screening procedure utilized at the University of Kentucky was used to screen 200 entries (100 entries per run) in the F_2 to F_7 generations. The procedure in-

volved planting approximately 10 to 15 seeds of an entry in two vermiculite-filled 50 ml polypropylene centrifuge tubes. About 4 weeks after seeding the seedlings were inoculated with the black shank fungus. Two weeks after inoculation the entries were scored on above ground plant parts (leaves and stems) and the roots. A scoring system of 0, 1, 2, 3 and 4 was utilized for the leaves and stems with a score of 0 representing no symptoms of the disease and a score of 4 representing complete death of all seedlings. A similar system was used for rating the roots. A rating of 0 represented no symptoms (roots white) and 4 represented severe browning of the entire root system.

Breeding for Mosaic Resistance. During the summer of 1975, 44 breeding lines in the F_2 to the F_7 generations were screened for mosaic resistance in the breeding nursery in the field. Each entry was represented by 28 plants. Just prior to flowering, plants were inoculated with the tobacco mosaic virus by rubbing the leaf with cheesecloth saturated in a solution of the virus. Approximately one week after inoculation, ratings were made on the number of resistant and susceptible plants in each entry. At the time of scoring the resistant plants exhibited small necrotic spots at the site of inoculation while the susceptible plants exhibited the characteristic mosaic pattern of dark and light green areas in the new growth. The necrotic spots of the resistant plants are due to a hypersensitive reaction of the leaf tissue to the virus. When the virus contacts the leaf cells, the cells die at such a rapid rate that the virus cannot spread.

Results

Black Shank Resistance. The results of the screening procedure for black shank resistance are presented in Table 1. Considerable variation was found among the entries for black shank resistance. A few entries ap-

peared to have complete resistance while others were completely susceptible. From the leaf and stem scores for the first run, 54% of the entries received a score of 1.5 or better while 22% of the root scores fell within this same range. Entries with a leaf and stem score of 1.5 would probably have adequate resistance under field conditions in southern Maryland. Data from the second run indicate a higher percentage of the entries were more susceptible than the entries in the first run.

One reason for the wide variation among the entries for black shank resistance could be due to the nature of inheritance of the resistance. Resistance from the Florida 301 source is believed to be dependent upon two major genes and several modifiers; therefore, through breeding the ultimate objective is to capture the two major genes and accumulate as many of the modifiers as possible. Resistance from L8 is simply inherited and produces plants with a very high level of resistance.

Mosaic Resistance. The results of the tobacco mosaic screening procedure are shown in Table 2. Resistance is determined by a single dominant gene; therefore, the plants fell into one of two classes -- resistant or susceptible. Screening results showed that all entries were resistant. For the entries, 16% appeared to be homozygous or true breeding and 84% were heterozygous or still segregating at the mosaic resistant locus.

Summary

Breeding lines with resistance to black shank and tobacco mosaic are being developed. Screening techniques which are relatively simple and reliable are being used in the greenhouse and summer breeding nursery. Lines with good resistance based on greenhouse and field results were advanced an additional generation in the field nursery during the summer. Selection for plant type and other desirable agronomic traits was done in the field nursery.

Some of the breeding lines which have good resistance and desirable plant types have been observed for agronomic acceptance in preliminary field trials under replicated conditions.

Literature Cited

1. Aycock, M. K., Jr., H. A. Skoog and B. W. Byrd, Jr. 1974. Maryland 872, a new variety of Maryland tobacco. Maryland Agr. Exp. Sta. MP 844.

2. Morgan, O. D. 1965. Maryland 59 and Maryland 609, two new tobacco varieties resistant to black shank for Maryland production. Maryland Agr. Exp. Sta. MP 538.

3. Skoog, H. A. and M. K. Aycock, Jr. 1969. Maryland 10: A mosaic resistant variety of Maryland tobacco. Maryland Agr. Exp. Sta. MP 734.

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Table 1. Percentage distribution of entries screened for black shank resistance in the greenhouse, 1976. (N = 100 per run)

Score class [a/]	1st Run		2nd Run	
	Leaves and stems	Roots	Leaves and stems	Roots
0.0	13	9	4	1
0.5	11	0	4	0
1.0	10	6	9	5
1.5	20	7	10	14
2.0	13	11	27	22
2.5	14	22	24	25
3.0	8	12	17	8
3.5	9	22	0	23
4.0	2	11	5	2

[a/] 0 = completely resistant; 4 = dead.

Table 2. Percentage of resistant (AA), segregating (Aa), and susceptible (aa) genotypes screened for tobacco mosaic resistance, field nursery, 1975. (N = 44).

Genotype	Breeding material, %
AA	16
Aa	84
aa	0

Performance of Breeding Lines in the Preliminary Variety Test, 1976

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Purpose and Objectives

The initial phase of a breeding program is developmental. Following a desired cross or series of crosses, selection for superior lines is conducted for a number of segregating generations. As new lines reach homozygosity information concerning agronomic and chemical performance is needed. The preliminary variety test is the initial screening process for new breeding lines. Superior breeding lines in this test are then included in the Official Variety Test for further evaluation.

Procedures

In 1975 a group of near homozygous lines with resistance to black shank and/or tobacco mosaic were selected from the tobacco breeding nursery for yield and quality evaluations. These breeding lines were field tested in 1976 at Upper Marlboro.

Thirty-two breeding lines and four standard varieties (Md. 872, Md. 10, Md. 64 and Md. 609) were included in the test. The experimental design was a randomized complete block with three replications. The various agronomic and chemical characteristics measured and methods of data collection have been outlined by Aycock, et al. (1). The quality index was determined by the procedure outlined by Mulchi (2).

Results

The performance of the 32 breeding lines and the standard varieties is shown in Table 1. Entry 25 exhibited the highest yield and dollar return per acre of all entries in the test. Entry 16 had the highest dollar per hundred-

weight value ($101.43) of all entries, but was not significantly higher than the standard Md. 609. Considerable variation was observed also among the various breeding lines for the quality index, days to flower and total alkaloids. After an additional seed increase in the breeding nursery, the top breeding lines from this test will be advanced to the Official Variety Test, and also used as breeding material in future crosses.

Summary

The performance of several breeding lines was very good when compared with the standard varieties. These breeding lines will be advanced to the Official Variety Test, and also used as breeding material in future crosses.

Acknowledgment

The computer time for the statistical analyses was made available through the facilities of the Computer Science Center of the University of Maryland.

Literature Cited

1. Aycock, M. K., Jr., H. A. Skoog, O. D. Morgan, C. G. McKee, J. H. Hoyert and C. L. Mulchi. 1975. Performance of Maryland tobacco varieties and breeding lines, 1973 and 1974. Maryland Agr. Exp. Sta. MP 884.
2. Mulchi, C. L. 1977. Development of an index of quality for Maryland tobacco. Maryland Agr. Exp. Sta. MP 909.

Table 1. Performance of breeding lines of Maryland tobacco in a preliminary variety trial at Upper Marlboro, Md., 1976.

Entry	Yield per acre (lbs.)	Value		Quality index (0-100)	Days to flower	Total alkaloids (%)
		$/A	$/cwt			
1	2340	2329	99.46	78.9	58.3	2.90
2	2447	2425	99.12	79.9	58.7	2.93
3	2463	2198	89.43	43.8	59.7	3.11
4	2616	2230	85.50	33.0	58.7	3.55
5	2539	2294	90.49	47.0	59.0	2.88
6	2642	2612	98.86	76.5	58.0	2.24
7	2666	2606	97.76	75.2	59.0	2.50
8	2317	2299	99.31	78.3	54.7	2.32
9	2306	2320	100.45	83.3	57.3	2.09
10	2518	2502	99.36	77.0	55.3	1.99
11	2370	2328	98.21	72.9	57.3	2.14
12	2392	2379	99.40	78.7	57.7	1.56
13	2437	2419	99.26	78.4	59.0	2.07
14	2597	2579	99.30	80.0	58.7	1.98
15	2406	2391	99.37	76.8	56.7	2.04
16	2377	2412	101.43	84.3	58.3	2.08
17	2498	2494	99.74	76.0	61.0	2.30
18	2522	2496	99.27	77.3	57.0	2.27
19	2274	2254	98.98	76.0	59.0	2.15
20	2156	2090	96.95	67.7	56.0	2.15
21	2716	2532	93.32	58.1	61.7	2.12
22	2408	2354	97.58	74.4	57.7	3.01
23	2659	2606	98.01	69.7	62.3	2.83
24	2451	2439	99.49	75.8	60.3	2.93
25	3224	2907	90.24	43.6	59.7	3.24
26	2684	2514	93.89	56.5	61.0	2.96
27	2925	2660	91.23	48.8	57.7	2.67
28	2827	2657	94.05	56.6	60.0	2.70
29	2405	2346	97.55	70.9	56.7	3.09
30	2577	2572	99.80	79.6	56.0	2.56
31	2493	2493	99.98	78.7	56.7	2.68
32	2659	2582	97.09	70.9	57.0	2.68
Md. 872	2615	2573	98.37	74.0	57.7	2.10
Md. 10	2553	2455	96.17	64.9	57.3	2.69
Md. 64	2925	2711	92.94	51.7	58.0	2.44
Md. 609	2574	2557	99.34	78.3	56.0	2.57
Mean	2544	2462	96.96	69.2	58.2	2.51
L.S.D. (5%)	370	357	3.82	12.4	3.7	0.83
(1%)	492	N.S.	5.09	16.6	5.0	1.11
C.V. (%)	8.9	8.9	2.4	11.1	4.0	20.4

No-Tillage vs. Conventional Tillage Corn Fertilization
I. Influence of Nitrogen Rate

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Purpose and Objectives

The purpose of this project was to continue studying the effects of nitrogen fertilization rates on no-tillage corn as compared to conventional tillage corn. With the no-tillage system obviously, it is not possible to plow down any of the nitrogen, phosphorus or potassium fertilizers, nor is it possible to incorporate recommended amounts of liming materials. By its very nature farmers utilizing the no-tillage concept must be content with applying lime and fertilizer to the soil surface. These materials cannot be incorporated deep into the plow layer. Under the conventional tillage system farmers are encouraged to plow down much of their fertilizer and lime. It has been demonstrated many times in the past that plowed down fertilizers normally resulted in higher yields than fertilizer broadcast on the surface or lightly disked-in.

Field observations throughout Maryland frequently have indicated that no-tillage corn may sometimes be more nitrogen deficient than conventional tillage corn grown at the same nitrogen fertilization rate. The purpose of this project was to compare no-tillage with conventionally tilled corn grown on well to somewhat poorly drained soils under several different rates of nitrogen fertilization. The main objective was to determine whether no-tillage corn could be efficiently fertilized at the same rates as conventionally tilled corn, or whether the nitrogen requirements of no-tillage corn were significantly different from those of conventional tillage corn.

Procedure

These tests were continued from previous years in the spring of 1976 at the Poplar Hill Research Farm near Salisbury, the Wye Institute near Queenstown, the Plant Research Farm near College Park, the Forage Research Farm near Clarksville, and the Maryland Correctional Institute Farm near Hagerstown. The soil types were Mattapex silt loam at Poplar Hill, Bertie silt loam at Wye Institute, Beltsville silt loam at the Plant Research Farm, Delanco silt loam at the Forage Research Farm and Hagerstown silt loam at the Maryland Correctional Institute.

A rye cover crop was established at all locations (except some of the new tests) on the no-till plots in the fall of 1975. The rye was killed with approximately one quart/A of paraquat and $1\frac{1}{2}$ lbs/A of atrazine and simazine. This material was applied approximately the first week of May. No cover crop was seeded in the conventional tillage plots. Pioneer 3369-A field corn was planted at Poplar Hill, the Plant Research Farm and the Forage Research Farm. Dekalb XL-64 was planted at Wye Institute, and Coker-16 was the variety utilized at the Maryland Correctional Institute Farm. Planting dates were May 11 at Poplar Hill, May 7 at Wye Institute, April 26 at the Plant Research Farm, and May 13 at the Forage Research Farm and the Maryland Correctional Institute Farm.

The fertilizer treatments were applied either prior to or immediately after planting. The treatments were as follows: no-tillage vs. conventional tillage and nitrogen at rates of 0, 40, 80, 120 and 160 lbs/A of N in a split plot design. The main plots were the tillage treatments and the sub-plots were the nitrogen treatments. At Poplar Hill and the Forage Research Farm the nitrogen source was ^{14}N labeled ammonium sulfate. At the other locations unlabeled ammonium nitrate was used. Phosphorus and potassium fertilizers were

applied uniformly to all plots according to soil test recommendations.

The plots were observed throughout the growing season and occasional nitrogen deficiency ratings were made on some plots as in previous years. Silage yields were harvested at Poplar Hill on August 24; silage yields were taken from the Wye Institute and the Forage Research Farm on August 31. As in previous years the silage harvest was accomplished by weighing six stalks at random from two of the rows. Stand counts, the weight of the six stalks and the moisture content were used to compute the silage yields in tons/A at 30% dry matter. The six stalks were passed through a small chopper. The chopped material was then mixed thoroughly and subsamples were removed for nitrogen analysis and moisture content.

Grain yields were harvested from all locations. Yields were measured by hand-harvesting and weighing the corn from a given length of row. A composite moisture sample was taken to convert yields to 15½% moisture. Grain yields were harvested on October 6 at Poplar Hill; October 7 at the Plant Research Farm and the Forage Research Farm; October 13 at the Maryland Correctional Institute and October 4 at the Wye Institute. A composite moisture sample was taken to convert yields to 15½% moisture.

Results

Grain yields are presented in Table 1. A significant response to nitrogen rate occurred at all locations. Maximum yields usually occurred at the highest nitrogen level. This response was true for both tillage systems. However, at one location conventional yields peaked at the 120 lbs N/A rate. Apparently the highest nitrogen rate applied was not sufficient for maximum yields on the no-tillage plots.

At the Poplar Hill location a significant nitrogen by tillage interaction occurred. Although not significant statistically, a similar trend was also apparent at the Forage Research Farm as well as at the Maryland Correctional

Institute and the Plant Research Farm. Generally, this interaction indicated that at low nitrogen levels conventional tillage corn yielded higher than the no-tillage corn. At higher nitrogen levels the reverse was true; conventional tillage corn yielded less than no-tillage corn.

At two of the five test locations, the mean grain yields for no-tillage and conventionally tilled corn were significantly different. At Poplar Hill, the highest average yield occurred with conventional tillage corn whereas at the Maryland Correctional Institute, highest yields occurred with the no-tillage corn. However, close examination of the data indicated that in these tests average over-all yields for the tillage systems were not as important as the yields for the tillage system at a given nitrogen rate. The nitrogen rate was extremely important in determining which tillage system had the higher yield potential. Although yields at all locations were quite good, rainfall in the Piedmont section of the state fell at much more appropriate times for the growing corn plant than often occurred on the Coastal Plain. Therefore, yields tended to be better in the Piedmont section of the state than in the Coastal Plain.

At Wye Institute, as nitrogen was increased grain yields increased equally under both tillage systems. At the Plant Research Farm grain yields on the check plots and the lowest nitrogen rate were the same for both tillage systems. However, at the higher nitrogen rates the no-tillage corn appeared to out-yield the conventional tillage corn. Grain yields at the Forage Research Farm followed the same trends observed at Poplar Hill and the Maryland Correctional Institute.

Silage yields at Poplar Hill, Wye Institute and the Forage Research Farm were increased significantly by nitrogen rates (Table 2). At Poplar Hill the conventionally tilled corn produced significantly higher nitrogen yields than no-tillage corn. However, at this location as well as at the Forage Farm, silage and grain yields followed similar trends. The highest silage yields occurred

under conventional tillage corn.

Total nitrogen recovery in the silage for several of the tests is reported in Table 3. Total nitrogen recovery following variable nitrogen rates was highest at Poplar Hill, Wye Institute and the Forage Farm in the conventional tillage plots. At all locations, nitrogen recovery increased significantly with increased nitrogen rate. As in previous years, the higher nitrogen recovery rate from the check plots at the Forage Farm reflected the higher residual nitrogen level at this location. However, these levels are now approaching more closely those at the Wye Institute.

Several years ago, severe weed control problems were observed at some of the tests at the Poplar Hill Farm in which up to 160 lbs/A of N had been applied as ammonium sulfate. It was theorized that this poor weed control may have been due to the development of extremely low pH in the surface soil as a result of nitrification of the ammonium sulfate. Research work at other experiment stations has demonstrated that low soil pH can deactivate the triazine herbicides and result in poor weed control. Soil samples were collected in 1975 and 1976 from three different depths on the N rate plots at Poplar Hill, the Wye Institute, the Plant Research Farm, the Forage Research Farm and the Maryland Correctional Institute. Data from the 1976 sampling is presented in Table 4. Soil pH in the surface one inch at all locations was generally lower as the nitrogen rates were increased. The lowest soil pH occurred following 160 lbs/A of N. At Poplar Hill, soil pH in the 0 - 1 inch layer was reduced from 6.0 to 4.8; at Wye Institute , from 6.2 to 5.4; at the Plant Research Farm from 6.4 to 4.8; at the Forage Research Farm from 6.8 to 5.7; and at the Maryland Correctional Institute from 6.5 to 5.6.

It was also observed at most locations that a soil sample taken from the 0 - 2 inch depth quite accurately reflected the pH in the 0 - 1 inch soil layer.

This observation was similar in previous years. The pH of the 0 - 8 inch sample, although indicating a reduction in soil pH as nitrogen rate was increased, did not accurately reflect the true change in soil pH of the surface layer.

Linear regressions and correlation coefficients were calculated for nitrogen recovery and grain yields under both tillage systems at Poplar Hill, Wye Institute, and the Forage Research Farm (Figures 1, 2, and 3). The regressions were similar to those calculated from the Poplar Hill data in 1973, 1974, and 1975. The differing slopes of the two regression lines clearly demonstrated that at low yield levels where nitrogen was the limiting factor, grain yields were higher from conventional than from no-tillage corn. At higher yield levels where nitrogen was not a limiting factor, grain yields at a given level of nitrogen availability were higher for no-tillage than for conventional tillage corn. This relationship between grain yields, nitrogen fertilization rate and tillage practices may vary due to numerous other factors limiting plant growth such as soil moisture, temperature, low soil pH, poor weed control, etc. However, the linear regressions as developed from the yield and nitrogen recovery data did reflect fairly accurately the yield and growth response often observed in the field.

Summary

1 - Under the variable soil and climatic conditions of these tests, at some locations average corn yields were higher for conventional than for no-tillage corn. At other locations either the reverse was true or there was no difference between the two tillage systems. Statistically, average conventional tillage grain yields were highest at one of the five locations tested. Average no-tillage grain yields were highest at one location. Grain yields were not significantly different at the other three locations. However, mean

tillage yields can be misleading due to the interaction effect with nitrogen treatment.

2 - At most locations, the data indicated that if available nitrogen levels were deficient, conventionally tilled corn produced higher yields than no-tillage corn. But where nitrogen levels were adequate, the two tillage systems were at least equal and in some cases the corn yields were higher for no-tillage than for conventional tillage.

3 - Soil samples collected from three different depths (0-1 inch, 0-2 inches, and 0-8 inches) indicated that high nitrogen fertilization rates on no-tillage corn resulted in significant soil pH depressions especially on the soil surface. These highly acid soils apparently result in deactivation of the triazine herbicides. A rate of 160 lbs/A of N from ammonium nitrate broadcast on the surface resulted in a soil pH reduction of 0.8 to 1.4 pH units. With 120 lbs/A of nitrogen from ammonium nitrate, a pH drop of 0.5 to 0.6 pH units occurred.

The data indicated that a soil sample collected from the 0 - 2 inch depth will accurately reflect the soil pH change in the surface layer. However, a sample taken from the 0 - 8 inch depth will not accurately reflect the pH changes on the surface.

Again, as observed in 1975 it is probable that when the soil pH ranges from about 6.2 to 6.5 before nitrogen is applied in the spring it is less likely that at the 120 lbs/A of N rate soil pH at the surface will be reduced sufficiently to cause a significant reduction in the activity of the triazine herbicides. But if the soil pH at the surface is below 6.2 before nitrogen application and if the triazine herbicides are being depended upon for weed control there may be a serious weed control problem if an adequate liming program is not conducted.

Table I. Grain yields of no-tillage and conventional tillage corn following variable nitrogen rates at five locations. 1976.

Tillage	N (lb/A) 0	40	80	120	160	Mean
	Bu/A (15.5% H_2O)					
Poplar Hill (#1)						
No-Tillage	34.7	81.5	92.0	129.1	154.1	98.3 *
Conventional	64.4	99.3	114.7	119.8	136.4	106.9
Mean	49.6	90.4	103.4	124.4	145.2	
	$LSD_{.05}$: N = 16.5 Bu, N x Tillage = 23.3 Bu.					
Wye Institute (#1)						
No-Tillage	68.4	97.7	133.0	150.2	151.2	120.1
Conventional	70.7	107.8	132.8	146.6	147.6	121.1
Mean	69.5	102.7	132.9	148.4	149.4	
	$LSD_{.05}$: N = 12.6 Bu.					
Plant Research Farm (#1)						
No-Tillage	18.1	47.5	94.8	122.9	139.0	84.5
Conventional	18.5	51.1	66.4	87.0	111.7	66.9
Mean	18.3	49.3	80.6	104.9	125.4	
	$LSD_{.05}$: N = 16.0 Bu.					
Forage Research Farm (#1)						
No-Tillage	109.7	135.8	146.3	159.2	170.8	144.4
Conventional	125.0	144.7	165.9	168.0	156.4	152.0
Mean	117.3	140.3	156.1	163.6	163.6	
	$LSD_{.05}$: N = 14.9 Bu.					
Maryland Correctional Institute (#1)						
No-Tillage	79.2	144.6	173.2	184.5	195.2	155.3 *
Conventional	112.9	154.0	154.2	161.7	167.8	150.1
Mean	96.1	149.3	163.6	173.1	181.5	
	$LSD_{.05}$: N = 23.3 Bu.					

* Means for tillage significant at 5% level.

Table 2. Silage yields of no-tillage and conventional tillage corn following variable nitrogen rates at three locations. 1976.

Tillage	N (lb/A) 0	40	80	120	160	Mean
	Tons/A (30% D.M.)					
Poplar Hill (#1)						
No-Tillage	9.3	13.2	17.4	19.9	21.7	16.3 *
Conventional	15.6	17.7	19.1	20.1	18.8	18.2
Mean	12.4	15.4	18.3	20.0	20.2	
	$LSD_{.05}$: N = 1.9 TONS, N x Tillage = 2.8 Tons.					
Wye Institute (#1)						
No-Tillage	13.7	18.2	19.6	22.0	23.8	19.5
Conventional	15.6	19.2	22.0	23.5	26.8	21.4
Mean	14.7	18.7	20.8	22.8	25.3	
	$LSD_{.05}$: N = 2.1 Tons.					
Forage Research Farm (#1)						
No-Tillage	17.3	21.9	23.6	22.1	23.5	21.7
Conventional	18.3	21.1	22.1	22.3	22.3	21.2
Mean	17.8	21.5	22.9	22.2	22.9	
	$LSD_{.05}$: N = 1.6 Tons.					

* Means for tillage significant at 5% level.

Table 3. Nitrogen recovery by no-tillage and conventional tillage corn following variable nitrogen rates at five locations. 1976.

Tillage	N (lb/A) 0	40	80	120	160	Mean	
	N Recovery (lb/A)						
Poplar Hill (#1)							
No-Tillage	32.2	47.6	73.0	107.0	128.2	77.6	*
Conventional	58.2	80.0	113.8	138.2	137.0	105.5	
Mean	45.2	63.8	93.4	122.6	132.6		
	$LSD_{.05}$: N = 15.2 lbs						
Wye Institute (#1)							
No-Tillage	73.7	89.4	108.0	172.4	169.8	122.7	
Conventional	72.7	98.4	141.8	169.9	229.7	142.5	
Mean	73.2	93.9	124.9	171.2	199.8		
	$LSD_{.05}$: N = 23.9 lbs						
Forage Research Farm (#1)							
No-Tillage	76.4	108.9	124.0	127.6	151.0	117.6	
Conventional	81.2	112.8	132.6	154.1	158.3	127.8	
Mean	78.8	110.8	128.2	140.8	154.7		
	$LSD_{.05}$: N = 14.2 lbs						

* Means for tillage significant at 5% level.

Table 4. Influence of several nitrogen rates on soil pH under no-tillage corn as indicated by three soil sampling depths at five locations. 1976.

Sample Depth (in.)	N (lb/A) 0	40	80	120	160	Mean
	Soil pH					
			[1] Poplar Hill (#1)			
0 - 1	6.0	5.7	5.2	5.0	4.8	5.3
0 - 2	6.3	5.8	5.3	5.1	4.9	5.5
0 - 8	6.2	6.0	5.6	5.5	5.2	5.7
Mean	6.2	5.8	5.4	5.2	5.0	
$LSD_{.05}$: N = 0.2 pH, DEPTH = 0.2 pH						
			[2] Wye Institute (#1)			
0 - 1	6.2	5.6	5.4	5.4	5.4	5.6
0 - 2	6.2	5.9	5.6	5.4	5.3	5.7
0 - 8	6.4	6.2	6.2	6.1	5.8	6.2
Mean	6.3	5.9	5.8	5.7	5.5	
$LSD_{.05}$: N = 0.1 pH, Depth = 0.2 pH, N x Depth = 0.2 pH						
			[2] Plant Research Farm (#1)			
0 - 1	6.4	5.9	5.2	5.2	4.8	5.5
0 - 2	6.4	6.0	5.6	5.4	5.0	5.6
0 - 8	6.5	6.4	5.9	6.0	5.6	6.1
Mean	6.4	6.1	5.6	5.6	5.2	
$LSD_{.05}$: N = 0.1 pH, Depth = 0.2 pH, N x Depth = 0.3 pH						
			[2] Forage Research Farm (#1)			
0 - 1	6.8	6.2	5.7	5.7	5.7	6.0
0 - 2	6.7	6.4	5.9	5.5	5.5	6.0
0 - 8	6.7	6.4	6.1	5.8	5.9	6.2
Mean	6.7	6.3	5.9	5.7	5.7	
$LSD_{.05}$: N = 0.2 pH						
			[1] Maryland Correctional Institute (#1)			
0 - 1	6.5	6.2	6.1	5.9	5.6	6.0
0 - 2	6.6	6.4	6.0	5.8	5.5	6.0
0 - 8	6.4	6.4	6.2	5.8	5.6	6.0
Mean	6.5	6.3	6.1	5.8	5.6	
$LSD_{.05}$: N = 0.2 pH						

[1] Nitrogen source was ^{14}N labeled ammonium sulfate.

[2] Nitrogen source was ammonium nitrate.

Note: All soil samples taken after N applied and corn emerged.

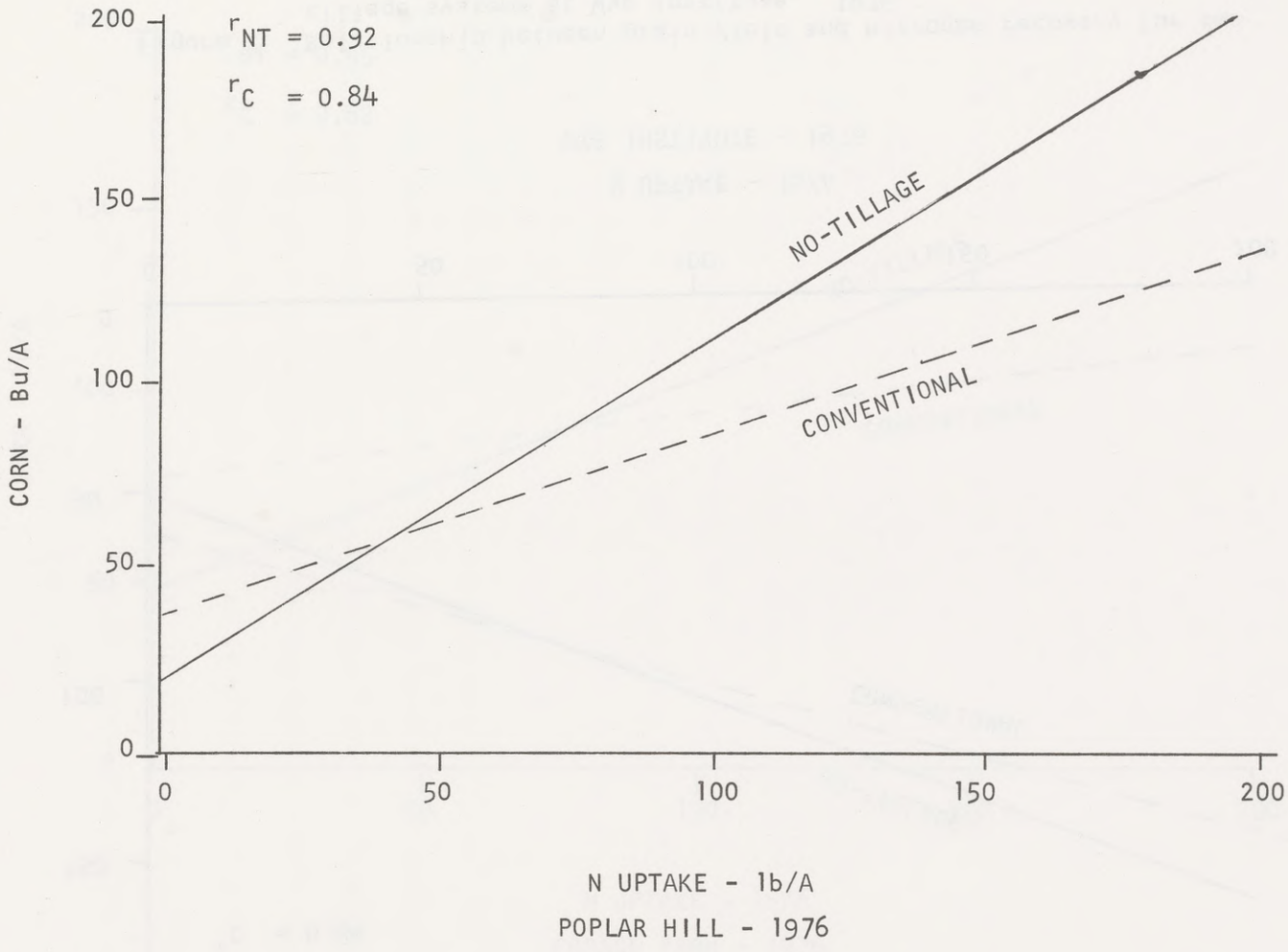

Figure 1. Relationship between grain yield and nitrogen recovery for two tillage systems at Poplar Hill. 1976.

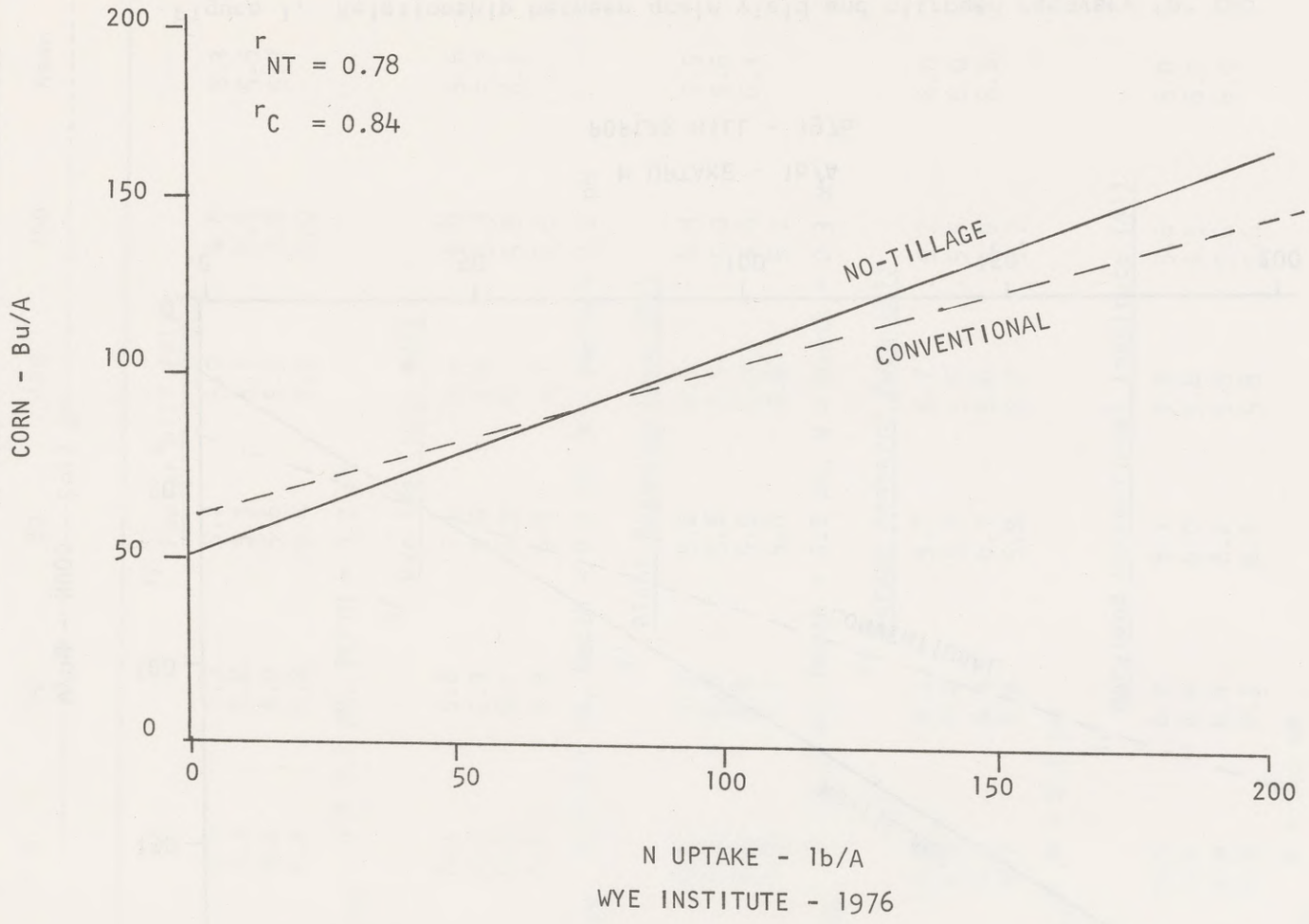

Figure 2. Relationship between grain yield and nitrogen recovery for two tillage systems at Wye Institute. 1976.

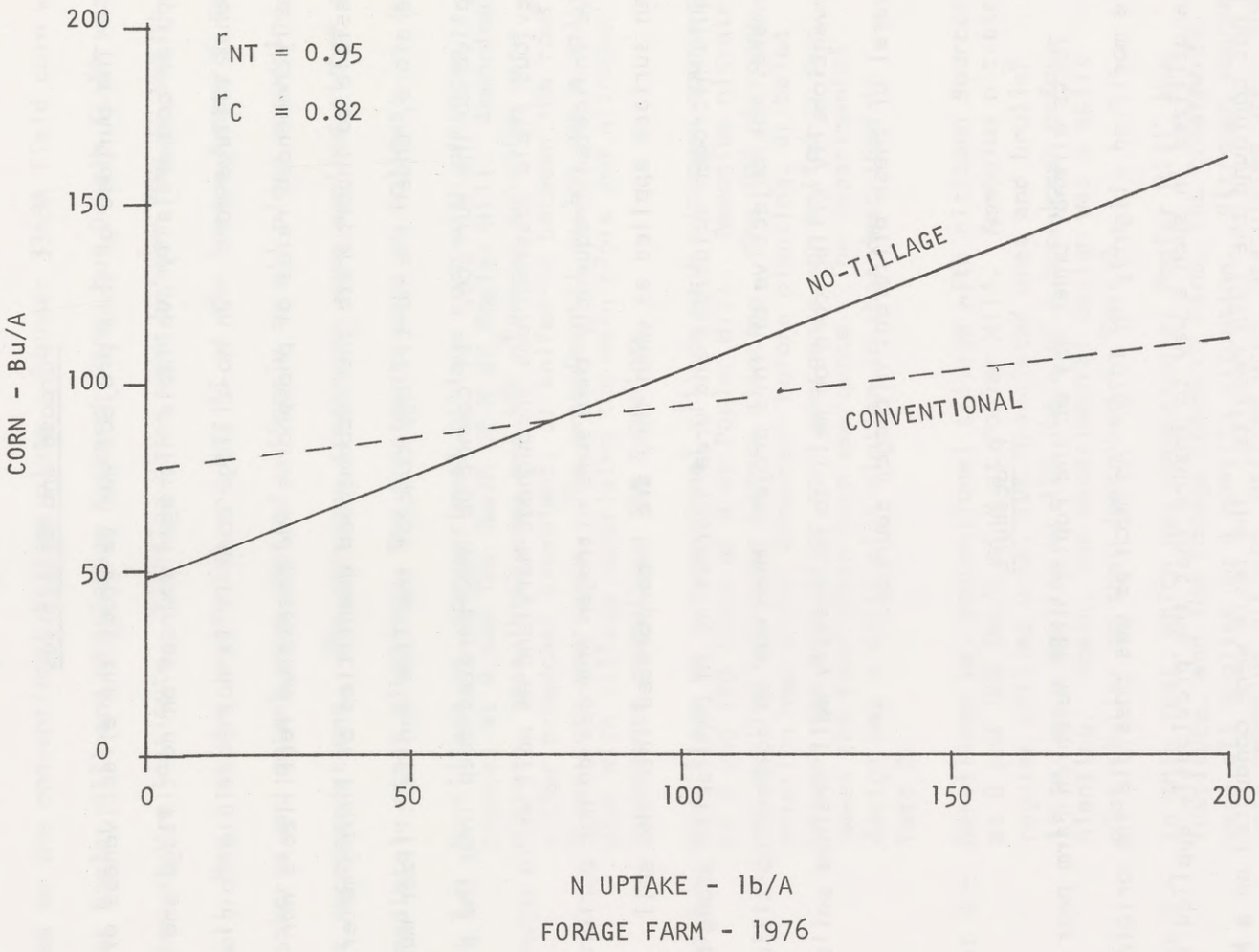

Figure 3. Relationship between grain yield and nitrogen recovery for two tillage systems at the Forage Farm. 1976.

No-Tillage vs. Conventional Tillage Corn Fertilization
II. Influence of Nitrogen Source

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Department of Agronomy

Purpose and Objectives

The purpose of this project was to study the effectiveness of several popular commercially available nitrogen sources on no-tillage and conventional tillage corn. On no-tillage corn it is not possible to plow down the recommended rates of phosphorus and potassium fertilizers nor is it possible to incorporate the recommended quantities of liming materials Therefore, under the no-tillage concept the lime and fertilizer must be applied to the surface. It cannot be incorporated deep into the plow layer. Previous field observations throughout Maryland as well as in other states have indicated frequently that some nitrogen sources do not perform as well when surface applied as when they are incorporated into the soil. With liquid nitrogen solutions and urea increasing in popularity among Maryland farmers, the objective of this project then was to compare no-tillage with conventionally tilled corn on well to moderately well drained soils utilizing several of these different nitrogen sources.

Procedure

Tests already under way at the Poplar Hill Research Farm near Salisbury were modified slightly in 1976. As much as was possible the original tests were utilized in such a way to insure that the previously applied treatments did not confound the 1976 results. The tests were conducted on a Mattapex silt loam soil at the Poplar Hill Research Farm near Salisbury. A new test in which four nitrogen sources were compared at five application rates was also established at the Poplar Hill Research Farm as well as at Wye Institute and the Forage Research Farm. The soils at these sites are given in the previous report.

On all but the new N rate x source test, the rye cover crop was established in the Fall of 1975 and killed with a quart of paraquat and 1 to 1½ lbs each of atrazine and simazine per acre the first week of May. No cover crop was seeded on the conventional tillage plots. Pioneer 3369A field corn was planted at Poplar Hill and the Forage Research Farm, but Dekalb XL-64 was substituted at Wye Institute. Planting dates were between May 11 and 14 at Poplar Hill; May 7 at Wye Institute; and May 13 at the Forage Research Farm.

Phosphorus and potash were applied uniformly to all plots according to soil test recommendations. The nitrogen treatments were applied either prior to or immediately after planting. The treatments were as follows:

Test 2 - No-tillage vs. conventional tillage corn with nitrogen sources at 0 and 120 lbs/A of N at Poplar Hill. Ammonium nitrate, granulated urea and 30% nitrogen solution were either broadcast pre-plant, or knifed-in between the rows after corn emergence. The experimental design was a split plot with tillage comprising the main plots and nitrogen treatments comprising the sub-plots.

Test 3 - No-tillage vs. conventional tillage with nitrogen sources at 0 and 120 lbs/A of N at Poplar Hill. Ammonium nitrate was applied broadcast before planting. The 30% nitrogen solution was either broadcast before planting, dribbled between the rows after corn emergence, or knifed-in between the rows after corn emergence. The experimental design was a split plot similar to that described in Test 2.

Test 4 - No-tillage vs. conventional tillage with nitrogen sources at 0 and 120 lbs/A of N at Poplar Hill. Ammonium nitrate, regular prilled urea, TVA granulated urea and broiler litter were applied at 120 lbs/A of N broadcast before planting. Again, the experimental design was a split plot similar to that described in Test 2.

Test 5 - In this test, which was conducted at Poplar Hill, Wye Institute, and the Forage Research Farm, the treatments were all applied to a no-till situation. Nitrogen sources were ammonium nitrate, prilled urea, granulated urea, and 30% liquid nitrogen solution applied at rates of 0, 40, 80, 120, and 160 lbs/A of N. At the Forage Research Farm one additional treatment of 200 lbs/A of N as ammonium nitrate was included. This experimental design was a randomized complete block. The plots were observed frequently throughout the growing season and occasional nitrogen deficiency ratings or height measurements were made on some plots.

Silage yields were harvested at Poplar Hill from Test No. 2, 3, and 4 on August 19. Silage yields were not harvested from Test No. 5 at Poplar Hill, Wye Institute and the Forage Research Farm. Silage yields were measured by harvesting six stalks at random from two of the corn rows and then weighing. Stand counts, the weight of the six stalks and moisture content were used to compute the silage yields in tons per acre at 30% dry matter. The six stalks were passed through a small chopper. The chopped material was mixed thoroughly and sub-samples were removed for nitrogen analysis and moisture content.

Grain yields were harvested from all locations. Yields were measured by hand-harvesting and weighing the corn from a given length of row. A composite moisture sample was taken to convert yields from $15\frac{1}{2}\%$ moisture. Soil samples were taken at three depths: 0 - 1, 0 - 2, 0 - 8 inches from Tests 2, 3, and 4. Soil analyses were conducted through the University of Maryland Soil Testing Laboratory.

Results

Field tests from previous years have indicated that some nitrogen sources do not always perform as well as others under no-tillage conditions. Under conventional tillage previous research data have indicated that ammonium nitrate, urea, and 30% liquid nitrogen solution are about equally available to the corn plant. However, under no-tillage conditions, urea and 30% liquid nitrogen solution have not always resulted in yields as high as those obtained from ammonium nitrate. Over the three year period, 1973-75, grain yields from urea averaged 19.1 Bu/A less than those from ammonium nitrate on no-tillage. This significantly lower yield was apparently due to ammonia volatilization losses from the urea. This is a frequent problem with urea when it is not incorporated into the soil. Similar problems

may occur with the 30% liquid nitrogen solution since they obtain 50% of their nitrogen from ammonium nitrate and 50% from urea.

Tests were conducted at Poplar Hill in 1976 to compare the various nitrogen sources under the two tillage systems utilizing different application methods (Tables 1, 2 and 3). In Test No. 2 at Poplar Hill (Table 1) nitrogen was applied at the rate of 120 lbs/A of N from ammonium nitrate, granular urea, and 30% liquid nitrogen solution. The ammonium nitrate, granular urea, and 30% N solution were broadcast pre-plant. In another treatment in this test, granular urea was knifed-in between the rows after the corn had emerged. The 1976 yield data is quite variable. Yields were approximately the same from all nitrogen sources and application methods under conventional tillage. But under no-tillage lowest yields occurred where the 30% nitrogen solution was broadcast pre-plant and where the granular urea was knifed-in between the rows after emergence.

It is possible that volatilization losses may have occurred from the 30% nitrogen solution under no-tillage. This material was applied with a standard garden type sprinkling can. Thus, the droplets were relatively large and the concentration of the urea in a given area may have been sufficient to create volatilization problems. It is not certain what may have happened to the granular urea knifed-in. This material was applied in a knife slot between the rows and incorporation with the soil was guaranteed by using a hoe to close the slot by hand after nitrogen application. It is apparent that nitrogen applied in this manner was not as efficiently utilized as the granular urea and ammonium nitrate broadcast. It is possible that plant growth may have been restricted somewhat due to the concentration of urea in the band, possibly due to the formation of ammonia or even due to the

formation of nitrite. Further work is needed to evaluate this application technique.

In Test No. 3 at Poplar Hill (Table 2) nitrogen was applied at the rate of 120 lbs/A of N with ammonium nitrate being utilized as the standard nitrogen source. This was compared to the 30% liquid nitrogen solution applied in three different ways: broadcast pre-plant, dribbled between the rows after emergence and knifed-in between the rows after emergence. Again, under conventional tillage the liquid nitrogen solution resulted in yields equivalent to the ammonium nitrate regardless of how the nitrogen solution was applied. However, under no-tillage, lowest yields from the liquid nitrogen occurred after the 30% solution had been broadcast on the surface. Knifing it between the rows resulted in slightly higher yields compared to the broadcast treatment. Highest yields from the nitrogen solution resulted after the solution had been dribbled between the rows. Again, because of the unexplained variability within these results these application methods for liquid nitrogen solutions on no-tillage should be further evaluated in future years.

Some explanation of the variability experienced in 1976 can be found perhaps in Table 3. This Table contains results from the No. 4 Test at Poplar Hill in which for the third year ammonium nitrate, prilled urea, granulated urea and broiler litter were compared broadcast on the two tillage systems. Unlike in previous years, the two urea sources when broadcast on the no-till plots resulted in yields which were equally as high or higher than those obtained from the ammonium nitrate. In previous years, surface applied urea resulted in lower no-till corn yields than ammonium nitrate. Apparently ammonium volatilization losses from urea were not as great in 1976 as in previous years. These reduced nitrogen losses perhaps may have been due to the extremely dry weather experienced during the early part of the growing season

at the Poplar Hill location. During dry weather, production of urease and subsequent enzymatic activity may have been restricted sufficiently to reduce the amount of urea converted readily to ammonia. These data demonstrate that although surface applied urea often resulted in lower no-till corn yields than ammonium nitrate, ammonia volatilization losses are variable and not always predictable. The efficiency of urea as a nitrogen source can be quite variable when it is not incorporated into the soil.

Based upon the frequent lower yields obtained from surface applied urea in previous years, it was decided in 1976 that there was a need to establish several tests in which prilled and granulated urea, 30% nitrogen solution and ammonium nitrate could be compared on no-tillage corn at several application rates. These tests (designated No. 5) were conducted at Poplar Hill, Wye Institute and the Forage Research Farm. Grain yields are found in Table 4. Since these tests were being conducted for the first time at each location and since residual soil nitrogen levels were expected to be relatively high in some cases, it was not expected that large yield differences would occur between N sources or even between nitrogen rates. But crop response varied with each location.

At Poplar Hill no statistically significant yield differences occurred as a result of nitrogen rate or of the four nitrogen sources.

At the Forage Research Farm yields were not influenced significantly by nitrogen source. However, a significant yield increase did occur as a result of increasing nitrogen rate. Apparently high residual soil N resulted in the check plot yielding 174.1 Bu/A. Yields increased from 174.1 to 201.8 Bu/A with the application of 200 lbs/A of N of ammonium nitrate.

At Wye Institute significant yield increases occurred due to nitrogen rate as well as to nitrogen source. The yield data at Wye Institute was similar to much of the data obtained in previous years in which at a given

nitrogen rate, ammonium nitrate resulted in highest yields on no-tillage corn. Urea, both prilled and granular, resulted in the lowest yields. The 30% nitrogen solution resulted in yields which were intermediate between the ammonium nitrate and the urea. These yield differences and relative ranking of nitrogen sources can be explained logically since the 30% nitrogen solution contains 50% of its nitrogen from urea. Ammonia volatilization losses from the 30% nitrogen solution would be expected to be less than those from urea. These tests will be continued in 1977 in an effort to determine if when using nitrogen sources which contain all or part of their nitrogen as urea, it will be necessary to apply them at higher rates than ammonium nitrate on no-tillage corn.

Corn silage yields under no-tillage and conventional tillage practices influenced by variable nitrogen sources and different methods of nitrogen application are reported in Tables 5, 6, and 7. Very little difference in silage yields were observed due to these treatments with the exception of broiler litter. Again, as with grain yields, nitrogen supplied by broiler litter was not as efficiently utilized as that from a commercial nitrogen source. However, even though grain yields were higher from broiler litter under conventional tillage than under no-till there was no difference between the two tillage systems for silage yields.

In those tests comparing nitrogen source and application method (Tables 8, 9, and 10) nitrogen recovery was always significantly higher on the conventionally tilled plots. Under no-tillage, highest nitrogen recovery was obtained from the ammonium nitrate. The lowest nitrogen recovery was obtained from the broiler litter. Although there was no significant difference between the two methods of application for urea and 30% nitrogen solution under conventional tillage, the highest nitrogen recovery apparently

occurred after the urea was knifed-in. It is doubtful that any of the nitrogen recovery differences between any of the treatments are significant.

In Table 9, where three application methods and two nitrogen sources (ammonium nitrate and 30% liquid nitrogen solution) are compared, the highest nitrogen recovery again was obtained from the conventional tillage. Lowest nitrogen recovery occurred under no-tillage where the 30% nitrogen solution was broadcast on the surface. However, again it is doubtful that any of these differences within the tillage treatments are significant.

In Test No. 4 at Poplar Hill (Table 10) ammonium nitrate, granular and prilled urea and broiler litter were compared under the two tillage systems. The highest nitrogen recovery again occurred under conventional tillage. Highest nitrogen recovery was obtained from the conventionally tilled ammonium nitrate plot. Lowest nitrogen recovery occurred from the no-tillage broiler litter plot. Again, differences in nitrogen recovery between the sources within the two tillage systems were not significantly different.

Soil samples were collected from the 0 - 1, 0 - 2, and 0 - 8 inch depths from two of the nitrogen source tests at Poplar Hill (Test 2 and Test 4). These data are presented in Tables 11 and 12. A somewhat larger drop in soil pH due to application of 120 lbs/A of N as ammonium nitrate, urea or nitrogen solution was observed in 1976 as compared to the drop observed in 1975. The 120 lbs/A of nitrogen as ammonium nitrate rate or treatment appeared to cause the soil pH in the top one inch to drop 0.5 pH units in one case and 0.8 pH units in another case. Urea resulted in 0.5 pH drop in both tests. The 30% nitrogen solution resulted in a 0.3 pH unit drop in one test and 0.5 pH in the other test. Broiler litter resulted in the smallest reduction in soil pH with a 0.2 pH unit reduction. Again, samples taken from the 0 - 2 inch depth quite accurately reflected the pH of the surface one inch of soil. However, samples

taken from the 0 - 8 inch depth often indicate a drop in soil pH of much lower magnitude than that observed in the surface layer. It must also be understood that these relative differences between sources probably change as nitrification proceeds.

Summary

A relatively large amount of variability occurred in the response of corn under the two tillage systems to the various nitrogen sources. In general, urea did not result in yields as high as those from ammonium nitrate under the no-tillage practice. Under conventional tillage all nitrogen sources, with the exception of broiler litter, resulted in equivalent yields. Under the no-tillage system in 1976, apparent ammonia nitrogen volatilization losses from urea appeared quite variable and not as large as in previous years. In some cases, under no-tillage, urea resulted in yields lower than those from ammonium nitrate. In other cases, yields were similar for ammonium nitrate and urea. Urea can give extremely variable nitrogen responses when applied to the soil surface and when soil incorporation is not possible. Apparently soil moisture deficiencies minimized urea volatilization losses in 1976 by restricting urease activity. Knifing-in urea or liquid nitrogen solution did not appear to be a satisfactory solution to prevent ammonia volatilization. The data indicated that no-tillage corn may require higher nitrogen rates where urea or 30% nitrogen solution are the nitrogen sources than where ammonium nitrate is utilized. This problem needs much further study.

The influence of 120 lbs/A of N on soil pH was measured in the top 8 inches of soil. In general there was very little difference between the effects of ammonium nitrate, urea and 30% liquid nitrogen solution. However, urea tended to not have quite as large effect on soil pH as ammonium nitrate. Broiler litter had the least effect.

Table 1. Grain yields of no-tillage and conventional tillage corn following application 120 lb/A of nitrogen from three sources and two application methods. 1976.

Tillage	N Source: Check	Amm. Nitrate [1]	Gran. Urea [1]	30% N Sol. [1]	Gran. Urea [2]	Mean
	Bu/A (15.5% H_2O)					
			Poplar Hill (#2)			
No-Tillage	39.8	161.4	160.7	135.2	133.6	126.1 *
Conventional	84.0	154.0	155.6	154.7	162.0	142.0
Mean	61.9	157.7	158.1	145.0	147.8	

$LSD_{.05}$: SOURCE = 15.8 Bu, Source x Tillage = 22.3 Bu

* Mean for tillage significant at 5% level.

1/ Broadcast pre-plant.

2/ Knifed-in between rows after emergence.

Table 2. Grain yields of no-tillage and conventional tillage corn following application 120 lb/A of nitrogen from two sources and three application methods. 1976.

Tillage	N Source: Check	Amm. Nitrate [1]	30% N Sol. [1]	30% N Sol. [2]	30% N Sol. [3]	Mean
	Bu/A (15.5% H_2O)					
			Poplar Hill (#3)			
No-Tillage	27.9	145.6	111.2	146.4	129.8	112.2 *
Conventional	72.3	146.3	142.3	147.8	148.8	131.5
Mean	50.1	145.9	126.7	147.1	139.3	

$LSD_{.05}$: SOURCE = 17.7 Bu.

* Mean for tillage significant at 5% level.

1/ Broadcast pre-plant.

2/ Dribbled between rows after emergence.

3/ Knifed-in between rows after emergence.

Table 3. Grain yields of no-tillage and conventional tillage corn following application 120 lb/A nitrogen from four sources. 1976.

Tillage	N Source: Check	Amm. Nitrate	Prilled Urea	Gran. Urea	Broiler Litter	Mean
	Bu/A (15.5% H_2O)					
			Poplar Hill (#4)			
No-Tillage	31.0	138.2	140.8	142.2	105.7	111.6 *
Conventional	79.8	136.1	148.5	150.0	142.0	131.3
Mean	55.4	137.2	144.6	146.1	123.8	

$LSD_{.05}$: SOURCE = 17.3 Bu, Source x Tillage = 24.5 Bu.

* Mean for tillage significant at 5% level.

Table 4. Grain yields of no-tillage corn following variable nitrogen rates from four nitrogen sources. 1976.

Source	0 [1]	40	80	120	160	200 [1]	Mean
	N (lb/A)						
	Bu/A (15.5% H_2O)						
Poplar Hill (#5)							
Amm. Nitrate	(113.4)	115.2	112.8	121.5	130.6	---	120.0
Prilled Urea	---	118.9	127.1	123.3	132.6	---	125.5
Gran. Urea	---	107.9	141.3	115.7	113.6	---	119.6
30% N Sol.	---	114.7	132.6	130.4	119.2	---	124.4
Mean	(113.4)	114.2	128.4	122.8	124.0	---	
Wye Institute (#5)							
Amm. Nitrate	(77.4)	117.0	138.4	135.4	133.6	---	131.1
Prilled Urea	---	98.0	97.4	107.7	127.5	---	107.6
Gran. Urea	---	98.3	109.4	100.5	114.7	---	105.7
30% N Sol.	---	90.6	104.0	135.4	130.6	---	115.2
Mean	(77.4)	101.0	112.3	119.7	126.6	---	
$LSD_{.05}$: RATE = 9.4 Bu., Source = 9.4 Bu., Rate x Source=18.8 Bu.							
Forage Research Farm (#5)							
Amm. Nitrate	(174.1)	181.8	191.1	186.6	188.2	(201.8)	186.9
Prilled Urea	---	166.8	182.5	184.3	195.7	---	182.3
Gran. Urea	---	175.9	190.6	192.2	180.7	---	184.8
30% N Sol.	---	173.0	176.8	191.8	191.8	---	183.4
Mean	(174.1)	174.4	185.2	188.7	189.1		
$LSD_{.05}$: RATE = 6.0 Bu., Rate x Source = 12.0 Bu.							

[1] Treatments in brackets not included in factorial analysis of variance for which $LSD_{.05}$ are shown above. All treatments are included in randomized complete block analysis for which $LSD_{.05}$ are shown.

$LSD_{.05}$: Poplar Hill = N. S.
Wye Institute = 18.6 Bu.
Forage Research Farm = 11.5 Bu.

Table 5. Silage yield of no-tillage and conventional tillage corn following application 120 lb/A of nitrogen from three sources and two application methods. 1976.

Tillage	Check	Amm. Nitrate [1]	Gran. Urea [1]	30% N Sol. [1]	Gran. Urea [2]	Mean
	N Source					
	Tons/A (30% D.M.)					
			Poplar Hill (#2)			
No-Tillage	10.5	19.0	18.5	18.9	18.2	17.0
Conventional	16.2	19.5	17.6	18.6	20.5	18.5
Mean	13.3	19.3	18.1	18.8	19.4	
	$LSD_{.05}$: Source = 2.3 Tons, Source x Tillage = 3.2 Tons					

[1] Broadcast pre-plant.

[2] Knifed-in between rows after emergence.

Table 6. Silage yield of no-tillage and conventional tillage corn following application 120 lb/A of nitrogen from two sources and three application methods. 1976.

Tillage	Check	Amm. Nitrate [1]	30% N Sol. [1]	30% N Sol. [2]	30% N Sol. [3]	Mean
	N Source					
	Tons/A (30% D.M.)					
			Poplar Hill (#3)			
No-Tillage	9.5	21.3	19.0	19.8	19.3	17.8
Conventional	14.8	20.3	19.5	19.9	22.9	19.5
Mean	12.1	20.8	19.3	19.8	21.1	
	$LSD_{.05}$: Source = 1.8 Tons, Source x Tillage = 2.6 Tons					

[1] Broadcast pre-plant.

[2] Dribbled between rows after emergence.

[3] Knifed-in between rows after emergence.

Table 7. Silage yield of no-tillage and conventional tillage corn following application 120 lb/A nitrogen from four sources. 1976.

Tillage	N Source: Check	Amm. Nitrate	Prilled Urea	Gran. Urea	Broiler Litter	Mean
	Tons/A (30% D.M.)					
			Poplar Hill (#4)			
No-Tillage	10.8	16.8	16.9	17.5	16.6	15.7 *
Conventional	12.3	19.5	18.9	19.2	16.2	17.2
Mean	11.5	18.2	17.9	18.4	16.4	

$LSD_{.05}$: Source = 1.8 Tons

* Mean for tillage significant at 5% level.

Table 8. Nitrogen recovery of no-tillage and conventional tillage corn following application 120 lb/A of nitrogen from three sources and two application methods. 1976.

Tillage	N Source: Check	Amm. Nitrate [1/]	Gran. Urea [1/]	30% N Sol. [1/]	Gran. Urea [2/]	Mean
	N Recovery (lb/A)					
			Poplar Hill (#2)			
No-Tillage	59.4	155.2	121.7	127.6	117.4	116.3 *
Conventional	86.4	186.7	174.2	177.0	203.0	165.4
Mean	72.9	171.0	148.0	152.3	160.2	
	$LSD_{.05}$: Source = 30.6 lbs					

* Mean for tillage significant at 5% level.

1/ Broadcast pre-plant.

2/ Knifed-in between rows after emergence.

Table 9. Nitrogen recovery of no-tillage and conventional tillage corn following application 120 lb/A of nitrogen from two sources and three application methods. 1976.

Tillage	N Source: Check	Amm. Nitrate [1/]	30% N Sol. [1/]	30% N Sol. [2/]	30% N Sol. [3/]	Mean
	N Recovery (lb/A)					
			Poplar Hill (#3)			
No-Tillage	51.1	162.9	142.8	145.4	158.3	132.1 *
Conventional	76.2	209.7	183.6	177.6	213.0	172.0
Mean	63.7	186.3	163.2	161.5	185.6	
	$LSD_{.05}$: Source = 26.9 lbs					

* Mean for tillage significant at 5% level.

1/ Broadcast pre-plant.

2/ Dribbled between rows after emergence.

3/ Knifed-in between rows after emergence.

Table 10. Nitrogen recovery of no-tillage and conventional tillage corn following application 120 lb/A nitrogen from four sources. 1976.

Tillage	N Source: Check	Amm. Nitrate	Prilled Urea	Gran. Urea	Broiler Litter	Mean
	N Recovery (lb/A)					
			Poplar Hill (#4)			
No-Tillage	50.3	130.4	154.4	161.0	97.3	118.7 *
Conventional	58.6	188.6	177.9	184.0	143.0	150.4
Mean	54.5	159.5	166.2	172.5	120.2	
	$LSD_{.05}$: Source = 27.5 lbs					

* Mean for tillage significant at 5% level.

Table 11. Influence of 120 lb/A nitrogen from three sources on soil pH under no-tillage corn as indicated by three soil sampling depths. 1976.

Sample Depth (in.)	Check	Amm. Nitrate	Gran. Urea	30% N Solution	Mean
	N Source				
	Soil pH				
			Poplar Hill (#2)		
0 - 1	6.1	5.6	5.6	5.8	5.8
0 - 2	6.1	5.8	5.8	6.0	5.9
0 - 8	6.1	6.1	6.2	6.1	6.1
Mean	6.1	5.9	5.8	6.0	

Note: All soil samples taken after N applied and corn emerged.

Table 12. Influence of 120 lb/A nitrogen from four sources on soil pH under no-tillage corn as indicated by three soil sampling depths. 1976.

Sample Depth (in.)	Check	Amm. Nitrate	Prilled Urea	Gran. Urea	Broiler Litter	Mean
	N Source					
	Soil pH					
			Poplar Hill (#4)			
0 - 1	5.6	4.8	5.1	5.1	5.4	5.2
0 - 2	5.8	4.8	5.0	5.0	5.5	5.2
0 - 8	6.0	5.5	5.6	5.4	5.7	5.6
Mean	5.8	5.0	5.2	5.2	5.6	

$LSD_{.05}$: N = 0.1 pH, Depth = 0.1 pH

Note: All soil samples taken after N applied and corn emerged.

No-Tillage vs. Conventional Tillage Corn Fertilization
III. Fertilizer Placement and Micronutrients on Poorly Drained Soils

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Purpose and Objectives

According to the Soil Conservation Service there are approximately 200,000 acres of poorly drained yet agriculturally important land in Maryland. Past experience has indicated that no-tillage corn does not seem to do as well on poorly drained soils, such as the Othello, Elkton, Keyport series, etc. as on better drained soils. These soil series are found on the Coastal Plain and are very important agriculturally. With adequate surface drainage these soils produce excellent yields when planted to conventional tillage corn. The purpose of this test was to make preliminary evaluation of broadcast vs. row fertilizer placement, no-tillage vs. conventional tillage and zinc vs. no zinc on a poorly drained Othello silt loam soil.

Procedure

In 1976, a new test (designated number 6) was established at the Poplar Hill Research Farm near Salisbury, Maryland. No-tillage and conventional tillage corn were compared on a poorly drained Othello silt loam soil. Other treatments included zinc vs. no zinc and broadcast vs. row fertilizer placement. A rye cover crop was established on the no-till plots in the Fall of 1975. The rye was killed with approximately one quart/A of paraquat and 1 - 1½ lb/A each of atrazine and simazine. This was applied approximately the first week of May. No cover crop was seeded on the conventional tillage plots. Pioneer 3369A field corn was planted at Poplar Hill on May 17. Phosphorus and potash were applied uniformly to all the plots according to soil test recommendations. On those plots which received row fertilization, the zinc was applied in the row

at $3\frac{1}{2}$ lbs/A as zinc oxide. In the broadcast fertilizer treatments the zinc was applied in the broadcast fertilizer at the rate of 7 lbs/A.

Results

Although observations early in the season indicated that vegetatively the conventionally tilled corn was growing better than the no-tillage corn no statistically significant grain yield differences occurred as a result of any of the treatments (Table I). This lack of response may have been due to the extremely dry weather experienced in 1976 during part of the growing season. This test will be repeated in 1977 when it is hoped that more normal growing conditions will prevail.

Summary

No grain yield response was obtained on the poorly drained Othello silt loam soil as a result of tillage practices. The no-till corn yielded equally as well as the conventional tillage corn. Also, there was no grain yield response due to row vs. broadcast fertilizer application nor was there response to the zinc fertilization.

Table 1. Grain yields of no-tillage and conventional tillage corn as influenced by zinc and row vs. broadcast fertilizer on poorly drained soil. 1976.

	Poplar Hill (#6)				
	Fertilization				
Tillage	Row + Zinc	Row - Zinc	Broadcast + Zinc	Broadcast - Zinc	Mean
	Bu/A (15.5% H_2O)				
No-Tillage	84.6	77.1	83.0	79.2	81.0
Conventional	84.2	81.8	88.1	102.0	89.1
Mean	84.4	79.5	85.6	90.6	
	Row	Broadcast	+ Zinc	- Zinc	
Mean	82.0	88.1	85.0	85.0	

Effect of Liquid Nitrogen Applications on Soil pH

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Purpose and Objectives

Triazine dissipation under No-Tillage cropping systems is suspected of being too rapid because of nitrogen applications. Techiniques were developed and several experiments were conducted to determine if pH effects from nitrogen applications can influence triazine breakdown. The present report restricts itself only to the interactions of nitrogen and pH. Triazine metabolism studies are presently in progress.

Procedures

Plastic Lermer vials (7 cm high with diameter = 3.5 cm) were used in all studies. The bottom of these vials were drilled with three equidistant 4 mm holes (used for extraction and drainage). The caps of the vials were punched out to give 3.2 cm disks which were placed in the bottom of the vials. The vials were then filled with either Lakeland sand, Chillum or Hagerstown loam. This soil was obtained from the A horizon, dried and passed through 10 mesh sieve before use. The soil filled vials were then placed in water until they were saturated and allowed to dry for 5 days until their water content was reduced to approximately field capacity. These vials were then sprayed with nitrogen solution in a laboratory sprayer at 38 psi to equal an application rate of 30 gpa or 100 lb of N per acre. The liquid nitrogen solution was sold as a 30% nitrogen solution containing 42.2% ammonium nitrate, 32.7% urea and 25.1% water. The state chemist's analysis found 31.1% nitrogen, 7.8% nitrate nitrogen and 15.4% urea nitrogen. After spraying nitrogen the vials were sprayed at the same application rate with one liter of distilled water. This application of less than 1 mm of water was applied to incorporate the nitrogen solution into the soil to reduce volatilization losses. Treated

vials were placed underneath a growth chamber at 25C and covered with a plastic film (Handi wrap) and periodically sampled for pH determination. The experiment was a randomized block design with 4 replications.

Results

The Lakeland (Table 1) and Hagerstown soil (Table 1) responded similarily to N additions and the response was highly dependent on time. From 0-5 days after N additions these soils had a higher pH than the controls. From 5-to 15 days, however, the pH rapidly decreased until it reached a value approximately $\frac{1}{2}$ of a pH unit lower than the controls. In the remainder of the experimental period the pH gradually increased but was still less than the controls at the end of the experimental period. The pH of the Chillum soil (Table 1) responded differently than the Lakeland and Hagerstown soils to N additions. The initial increase in pH in the Chillum was over one pH unit at the 0 to 0.5 cm depth. The pH subsequently decreased but unlike the other soils this decrease was gradual and was greater than the controls at the termination of the experiment (70 days). The initial pH of the Chillum soil was 5.2 and the Lakeland and Hagerstown soils had an initial pH of approximately 6.8. This difference was assumed to be a major factor in the differential response of Chillum compared to the other soils. An experiment on pH adjusted soils gave data to support this assumption.

The response to pH was also dependent on the depth of the soil sampled. At the 0 to 0.5 cm depth the pH response was greater than at all other depths. The pH response progressively decreased as the depth of sampling increased.

Summary

Application of liquid nitrogen to the surface of three soils indicated that a pH reduction may occur in the surface to such a magnitude that triazine breakdown may be affected. Reduction in pH in the upper cm caused by 100 lb/A nitrogen was approximately 0.5 pH unit for soils with an initial pH of 6.8.

Table 1. Change in pH from control as influenced by 100lb/A nitrogen. Values are negative unless preceded by a +.

Soil Type	Soil Depth	Days After Nitrogen Application 6	11	24	38	54	68
Lakeland	0-0.5	+0.3	0.55	0.40	0.0	0.30	0.50
Lakeland	0.5-1.0	+0.3	0.47	0.30	0.20	0.25	0.44
Lakeland	1.0-2.0	+ .15	0.30	0.17	0.20	0.24	0.38
Lakeland	2.0-4.0	+ .09	0.43	0.12	0.12	0.07	0.14
Hagerstown	0-0.5	+0.11	0.46	0.32	0.52	0.07	0.25
Hagerstown	0.5-1.0	+0.25	0.39	0.33	0.45	0.40	0.20
Hagerstown	1.0-2.0	0.02	0.40	0.34	0.25	0.37	0.17
Hagerstown	2.0-4.0	0.02	0.18	0.20	0.17	0.15	0.18
Chillum	0-0.5	+1.2	+1.30	+1.00	+0.45	+0.37	+0.25
Chillum	0.5-1.0	+0.80	+0.82	+0.97	+0.56	+0.72	+0.32
Chillum	1.0-2.0	+0.19	+0.20	+0.82	+0.43	+0.32	+0.10
Chillum	2.0-4.0	+0.07	+0.10	+0.18	+0.22	+0.05	0.06

Field Evaluation of HOE-29152 Pre and Post Emergence on Johnsongrass in Soybeans

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Purpose and Objectives

HOE-29152 is a new diphenyl diether herbicide which may be effective in controlling johnsongrass post emergence. The following experiment was conducted to determine the effectiveness of HOE-29152 on johnsongrass control.

Procedures

The experimental site was at Poplar Hill on a Galestown loamy sand. Plots were 10 by 30 feet with 30 inch row spacing and were replicated two times in a randomized block design. Herbicides were applied in 30 gpa on May 21, 1976 and June 19, 1976 for pre, early post and late post, respectively. The variety of soybeans was Essex.

Results

HOE-29152 had more activity post emergent than pre emergent (Table 1). Rates of 3-4 lb/A were necessary for adequate control pre emergent, however, 1.5 lb/A gave excellent control by 8/4/76 when applied at the late post stage. Early post was less effective than late post. Additional surfactants did not affect crop phytotoxicity or johnsongrass control of the herbicide. Temporary soybean injury occurred at rates as low as 1.5 lb/A, however, rates as high as 5 lb/A did not reduce yields nor did visual injury remain after 6/30/76.

Summary

HOE-29152 appears to have promise as a post emergent johnsongrass control herbicide. Rates of 1.5 lb/A give excellent control with little soybean injury when applied at the late post emergent stage.

Table 1. Evaluation of HOE-29152 pre and post emergence on johnsongrass in soybeans

Treatment	Rate (lb./A)	Timing	Crop Phytotoxicity Ratings*				Johnsongrass control*					Soybean Yield(lbs.per 2-30 ft.rows	
			6/19	6/22	6/30	7/14	6/19	6/22	6/30	7/14	8/4	Rep.A***	Rep.B***13% H_2O)
Control	--	--	0.0	0.0	0.0	0.0	0.0	0.0	3.5	2.5	0.0	4.2	0.9
HOE-29152	0.75	Pre	0.0	0.0	0.0	0.0	3.0	3.5	5.0	2.0	2.5	4.9	4.0
HOE-29152	1.50	Pre	0.0	0.0	0.0	0.0	4.0	0.0	5.0	1.0	4.0	7.3	5.3
HOE-29152	3.00	Pre	0.0	0.0	0.0	0.0	8.0	6.5	6.5	7.0	4.5	5.2	4.0
HOE-29152	4.00	Pre	0.0	0.0	0.0	0.0	8.5	7.0	6.5	7.0	5.0	5.1	5.4
HOE-29152	1.50	Early Post	1.0	0.0	0.0	0.0	3.0	2.5	7.0	5.5	4.5	5.3	6.5
HOE-29152	3.00	Early Post	1.0	0.0	0.0	0.0	7.5	9.0	8.0	8.5	9.5	7.0	7.0
**HOE-29152	4.00	Early Post	5.5	0.0	0.0	0.0	9.0	8.5	6.0	9.5	9.0	4.3	4.2
**HOE-29152	5.00	Early Post	5.0	0.0	0.0	0.0	9.5	10.0	7.5	10.0	10.0	8.3	6.9
**HOE-29152	1.50	Late Post	0.0	2.5	1.0	0.0	0.0	7.5	7.5	9.0	10.0	8.1	7.6
**HOE-29152	3.00	Late Post	0.0	2.5	1.0	0.0	0.0	8.5	7.5	9.5	9.5	6.0	8.5
**HOE-29152	4.00	Late Post	0.0	3.0	1.0	0.0	0.0	9.5	8.0	9.5	9.5	6.4	8.2
Control (Hand-weeded)	-	--	0.0	0.0	0.0	0.0	0.0	9.5	7.0	5.0	10.0	4.0	7.1
HOE-29152 + 1.50+ Booster + E 2 qts.		Late Post	0.0	2.5	2.0	0.0	0.0	8.5	7.5	9.0	9.0	6.4	7.7
HOE-29152 + 4.00 + Booster + E 2 qts.		Late Post	0.0	3.5	1.0	0.0	0.0	8.0	8.5	9.5	9.5	5.3	4.8

* Mean of 2 replications: 0= no injury/control, 10=complete death/control

** X-77 (0.5% v/v) added

*** Rep.A=no johnsongrass pressure
Rep.B=heavy johnsongrass pressure

The Influence of Variety, Stage of Growth and Surfactant on HOE-29152 Injury to Soybeans

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Purpose and Objectives

Presently johnsongrass can be controlled in soybeans by dinitroaniline herbicides. These treatments are expensive, must be incorporated and give less than the desired control. HOE-29152 is a new diphenyl diether herbicide which is useful in selectively controlling johnsongrass post emergent in soybeans. The present studies were conducted to determine the influence of variety, stage of growth and surfactant on toxicity of high rates of HOE-29152 on soybeans.

Procedures

Four thiram treated seeds of 16 varieties (Table 1) of soybeans were planted 1 cm deep in 2 x 2 inch plastic pots filled with a potting mixture of equal parts of soil, peatmoss and perlite. These pots were placed on a greenhouse bench in a randomized block design with three replications. In addition thirteen extra Forrest pots were planted; three of which were used for treatments without X-77 and ten for plants to be treated at flowering. All pots were fertilized every two weeks with one gram of 2-15-30. All pots were thinned to one plant after emergence. At this time the plants to be sprayed during flowering were also transplanted into 6 inch diameter plastic pots. Herbicide application of HOE-29152 (3EC) was made with a laboratory sprayer at 38 psi, 30 gpa, with a 8002E hozzle tip traveling at 2 mph. The application to the plants at the second trifoliate leaf occurred 28 days after planting on a hot sunny day (8 am) with the greenhouse temperature at 80°F. Spraying at the fifth trifoliate leaf and the plants in flower occurred 56 days after planting (11 am) a cloudy day with a temperature of 70°F.

Results

Injury of soybean varieties of the second trifoliate leaf occurred within one day after treatment and reached a maximum at approximately three days after treatment (Table 1). Recovery was noticable as soon as seven days after treatment. Although there was a significant difference in the height of the varieties at spraying the injury ratings were generally not significant. The increase in the error mean square at 10 days after spraying is the result of a few plants being injured or killed because of lack of water. The Forrest with X-77 had injury ratings similar to Forrest without X-77. It appeared, therefore, that X-77 had no effect on HOE-29152 activity.

Injury to soybean varieties by HOE-29152 at the fifth trifoliate stage (Table 2) was more difficult to decipher than at the second trifoliate leaf stage. This occurred because many plants were injured before spraying for the same reasons as stated above. In general, however, the results and conclusions appear to be the same for the two different growth stages.

Plants treated at flowering (Table 3) were of the same age as those treated in the fifth trifoliate leaf stage. The flowering plants were, however, much larger because they were growing in larger pots and were never subject to drought conditions. Injury ratings were somewhat higher with these plants than with plants with 2 and 5 trifoliate leaves. It is assumed that the greater injury occurred because these plants were growing under more favorable conditions and, therefore, their foliage was more easily penetrated by the herbicide. Surfactant appeared to cause a slight improvement in HOE-29152 activity. Statistical analysis cannot, however, be performed on this data.

Summary

Sixteen soybean varieties were sprayed at the second and fifth trifoliate leaf stage with 3lb/A of HOE-29152 plus 0.5% X-77. In addition the Forrest variety was sprayed at the second trifoliate leaf stage with 3lb/A of HOE-29152

both with and without X-77. Results indicate that injury to soybeans caused by 3lb/A of HOE-29152 is not affected by variety, stage of growth or surfactant. In general injury of 50-70% of the above ground plant parts occurred within a few days after HOE-29152 application at 3lb/A. Recovery occurs, however, after several weeks.

Table 1. Phytotoxicity of HOE-29152 (31b/A) to 16 Soybean Varieties at the Second Trifoliate Leaf Stage.

Variety	Plant characteristics at time of spraying		Visual Injury Rating*								
	Height (cm)	Number of Trifoliate leaves	Days after spraying 3	7	10	21	28	31	38	44	mean
Woodworth	11.3	1.4	5.0	4.0	4.0	1.0	0.7	0.7	.7	.7	2.1
Delmar	11.3	1.6	5.0	3.3	3.7	1.3	0.7	0.3	1.3	4.0	2.5
Cutler 71	11.3	1.5	5.3	4.3	3.3	1.3	0.7	0.3	1.3	0	2.1
Kent	10.7	1.6	3.7	4.0	3.0	6.7	6.0	6.3	5.7	4.0	4.9
Williams	10.3	1.2	4.3	3.7	3.3	4.7	3.7	3.7	4.0	3.3	3.8
Columbus	8.3	1.7	5.7	3.3	3.3	1.3	0.7	0.3	.3	0	1.9
York	12.7	2.0	4.3	5.3	3.3	1.0	0.7	0.7	.3	1.0	2.1
Essex	12.7	1.4	5.0	4.0	3.0	1.7	0.7	1.0	1.0	.7	2.1
Wayne	11.0	1.3	4.0	4.7	3.3	2.7	1.3	1.0	4.3	1.0	2.8
Shore	10.3	1.6	5.7	3.3	4.7	3.3	3.0	2.3	3.0	2.0	3.4
Beeson	11.7	1.6	4.7	4.0	3.7	1.7	1.0	1.0	.7	1.3	2.3
Corsoy	10.3	1.5	4.7	3.7	4.7	2.7	2.0	2.3	3.7	2.0	3.3
Calland	11.7	1.6	4.3	3.7	3.7	4.0	3.3	3.3	3.3	4.7	3.8
PI-71,506	9.3	1.6	5.3	4.3	3.7	6.3	5.3	4.7	5.3	4.0	4.9
PI-181,550	12.0	1.6	4.7	3.3	4.0	1.0	1.3	1.3	2.7	2.0	2.5
Forrest	12.7	1.7	4.7	2.7	5.0	4.7	3.7	3.7	4.0	6.7	4.4
Forrest**	13.3	1.6	4.0	4.0	2.7	2.3	6.0	2.0	.7	0	2.7
Mean	11.2	1.6	4.7	3.9	3.6	2.8	2.4	2.1	2.4	2.2	
Statistical Significance	1%	N.S.	N.S.	N.S.	N.S.	5%		N.S.	N.S.	N.S.	
Error mean square			1.2	1.6	1.5	4.7	6.8	7.6	8.6	10.5	

*0= No injury, 9= all tissue necrotic except the stem, 10=all tissue necrotic=death.

**Sprayed without X-77. All other treatments were sprayed with 0.5% X-77.

N.S.

Table 2. Phytotoxicity of HOE-29152 (3lb/A) to 16 Soybean Varieties of the Fifth Trifoliate Leaf Stage.

Variety	Plant Characteristics at time of Spraying		Visual Injury Rating* Days after spraying				mean
	Height (cm)	Visual Injury Rating**	3	7	10	16	
Woodworth	19.0	4.3	7.0	6.0	6.3	5.0	6.1
Delmar	25.0	0	4.6	5.0	4.0	2.0	3.9
Cutler 71	22.0	1.0	5.0	4.0	4.0	4.3	4.3
Kent	22.3	3.0	6.0	5.3	4.7	4.0	5.0
Williams	18.7	4.0	6.7	6.3	6.0	6.0	6.3
Columbus	22.0	1.3	6.3	5.3	5.0	3.0	4.9
York	24.7	0	3.7	4.3	4.0	2.3	3.6
Essex	26.3	3.0	6.7	7.0	4.3	5.0	5.8
Wayne	22.0	1.7	6.7	6.0	7.0	3.0	5.7
Shore	19.3	0.3	5.0	4.3	4.3	2.0	3.9
Beeson	26.0	1.0	6.0	4.3	3.7	1.7	3.9
Corsoy	17.3	1.7	6.3	4.6	4.3	3.3	4.6
Calland	24.0	0.7	6.0	5.3	5.0	5.3	5.4
PI-71,506	23.7	0	5.0	5.0	4.0	1.7	3.9
PI-181,550	22.3	5.7	8.3	7.3	7.0	6.7	7.3
Forrest	33.3	0	4.3	4.3	4.0	2.3	3.7
mean	23.0	1.7	5.9	5.3	4.9	3.6	
Statistical Significance	1%	N.S.	N.S.	N.S.	N.S.	N.S.	
Error mean sq.	11.9	6.6	2.6	2.7	2.5	7.1	

* 0= No injury, 9= all tissue necrotic except the stem, 10= all tissue necrotic=death.

Table 3. Phylotoxicity of HOE-29152 (3 lb/A) to Forest Soybeans in the Flowering Stage.

Treatment	Visual Injury Rating* Days after Spraying 3	7	10	16
HOE-29152+0.5% x-77**	8.7	7.0	5.3	2.0
HOE-29152***	7.5	6.5	4.5	2.0
Control****	0	0	0	0

* 0= no injury, 9=all tissue necrotic except the stem, 10=all tissue necrotic=death.
** mean of 3 plants
*** " " 2 "
**** " " 5 "

Alfalfa Variety and Strain Tests

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Purpose and Objectives

Considerable effort in public and private breeding programs is directed at developing alfalfa varieties adapted to Maryland conditions. The objectives of this work are to: (1) compare existing public and private varieties in yield and persistence, and (2) evaluate advanced strains being developed for possible release as varieties for use in Maryland.

Procedure

Two tests were harvested in 1976. Both were located at the Forage Research Farm on the Elsinboro silt loam. The first test was established in spring, 1973, and a soil test made in March, 1976, showed a pH of 6.4 and MgO, P_2O_5 and K_2O in the medium range. The second test was established in March, 1976. Prior to establishment, a soil test showed a pH of 6.2 with MgO in the high range and P_2O_5 and K_2O in the medium range. Just before seeding 1.75 tons of high calcium limestone (50% total oxides) per acre and 1,000 tons of 0-10-20 per acre were applied. The 1973 test was harvested four times and the 1976 test three times.

Results

Dry matter yields for the two tests are shown in Tables 1 and 2. Entries are ranked in the tables according to yield from highest to lowest. The spread in yields was greater in the 1973 test than in the 1976 test because the plants in the older stand were beginning to show persistence or lack of persistence traits. Lines with anthracnose resistance were top yielders in the 1973 test.

Summary

Two variety tests which had been established in 1973 and 1976 were harvested four and three times respectively in 1976. Yields ranged from 5.2 to 3.3 tons per acre in the 1973 test and from 4.3 to 3.5 tons in the 1976 test. Anthracnose resistant lines showed the greatest yields and persistence in the 1973 tests. Less spread was evident in the new, 1976 test.

Table 1. 1976 dry matter yields from four harvests. 1973 alfalfa strain and variety test at Clarksville, Maryland.

Alfalfa Entry	Seasonal Yield* (T/A)
Saranac AR	5.2 a
Beltsville 71 (FC40851) 1/	5.0 ab
Beltsville 72	4.9 abc
NCW 20b	4.9 abc
Beltsville MSH $_{D}$ 6FAn4W4Sb2W2	4.8 abc
Beltsville 71 (FC40891) 1/	4.8 abc
Beltsville MP2	4.8 abc
WL311	4.8 abc
NCW18b	4.7 abcd
Weevlchek	4.7 abcd
D69	4.7 abcd
Beltsville 3An4	4.6 abcd
WL305	4.6 abcd
Appalachee	4.6 abcd
Beltsville 1An4	4.5 bcd
Thor	4.5 bcd
Appalachee Phyto 2	4.4 bcd
Glacier	4.4 bcd
NCW20a	4.4 bcd
Williamsburg	4.2 de
Saranac	4.1 e
Team	4.1 e
Vernal	3.8 ef
NK Spredor	3.3 f

* Any two means which are not followed by the same letter are significantly different at the 1% level. Duncan's Multiple Range Test.

Table 2. 1976 dry matter yields from three harvests. 1976 alfalfa strain and variety test at Clarksville, Maryland.

Alfalfa Entry	Seasonal Yield* (T/A)
Saranac AR	4.3 a
Atlas	4.2 ab
Olympic	4.2 ab
Gladiator	4.1 abc
WL 311	4.1 abc
WL 318	4.1 abc
R/A 3	4.1 abc
Victor	4.1 abc
NAPB-51	4.0 abc
Pioneer 530	4.0 abc
Arc	4.0 abc
Pioneer 521	3.9 abc
Williamsburg	3.7 abc
Lancer	3.6 bc
Appolo	3.6 bc
WL 219	3.5 c

* Any two means which are not followed by the same letter are significantly different at the 1% level. Duncan's Multiple Range Test.

Corn Silage Variety and Strain Test

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Purpose and Objectives

Variety tests to evaluate corn for grain are conducted each year in several locations throughout the state. The best yielding grain varieties are frequently the best silage varieties, but not always. Leafy, robust plants with good ear development produce the greatest tonnage of high energy silage. A test was conducted to identify superior silage varieties and experimental lines.

Procedure

Forty-one experimental lines and commercial varieties of corn were seeded on June 5, 1976 at the Forage Research Farm, Clarksville. The site selected was a Chester silt loam with a pH of 6.3, high in MgO and medium in P_2O_5 and K_2O. Prior to planting, 120-80-80 fertilizer was disced in. The varieties were planted in 4-row plots using an International Harvester air planter. The plot size was 10 X 30 feet. Seeding rate was 25,000 plants per acre; however, the planter did not consistently seed at this rate. Each variety was replicated four times. Atrazine and simazine were used for weed control. The plots were harvested on September 18, 1976. One center row 15 feet in length was harvested from each plot. Broken stalks were counted in the harvest strip along with the total plant count. Green weights were obtained and a moisture sample was oven dried to determine the dry matter percent. Silage yields were calculated based on 35% dry matter silage.

Results

Plant populations ranged from 16,800 to 31,000 per acre; however, most

varieties were in the 22,000 to 25,000 range. Broken stalks varied from none to 19%, but most entries had 5% or less. Yields ranged from almost 24 tons per acre to slightly less than 14 tons. The low yielding entry was the old open pollinated variety, Reid's Yellow Dent. Data on yield, population, and broken stalks are shown in Table 1.

Summary

Forty-one corn varieties or experimental lines were compared for silage yields in a study conducted at the Forage Research Farm, Clarksville. Data were also obtained on the number of broken stalks at harvest time. Yields of 35% dry matter silage ranged from nearly 24 tons per acre to slightly less than 14 tons. The $LSD_{.05}$ was 4.4 tons. The lowest yielding variety was the old open pollinated variety, Reid's Yellow Dent.

Table 1. 1976 Corn silage variety test - Clarksville

Plots 10' X 30' (4 rows) | Harvest Strip 1 Row X 15' | Planted - June 5 Harvested Sept. 18

Variety	35% DM Silage Tons/acre	Plant Population Plants/acre	Broken Stalks %
1. Experimental 2	23.9	31,000	0
2. Experimental 4	23.2	24,000	4
3. Funk G 4646	22.6	23,800	4
4. Voris 2642	21.4	22,600	0
5. Acco U 395	21.4	22,600	5
6. Pioneer 3369A	21.2	20,600	4
7. Experimental 16 (white)	21.2	24,000	5
8. Funk G 5666	21.1	23,500	7
9. Agway 840X	20.7	22,000	9
10. Experimental 17 (white)	20.6	23,200	1
11. Asgrow RX94	20.2	18,800	0
12. Doebler 85X-A	19.9	23,200	5
13. PAG 314	19.9	26,100	7
14. Experimental 1	19.2	24,000	1
15. Southern States 750	19.2	23,500	1
16. Voris 2562	19.1	23,800	4
17. Kenworthy KLX69A	19.1	22,000	0
18. Experimental 5	18.9	22,300	6
19. Experimental 15 (white)	18.9	22,000	19
20. Trojan TXS 117A	18.9	23,200	4
21. Golden Harvest H2500	18.8	22,600	13
22. Experimental 11	18.6	22,300	3
23. Beachley-Hardy 120X	18.6	22,900	3
24. Northrup-King PX76	18.6	22,000	3
25. Experimental 3	18.2	24,600	9
26. Experimental 7	18.2	22,600	6
27. Experimental 6	18.1	25,800	4
28. Experimental 8	17.8	25,100	0
29. Experimental 46	17.6	22,000	4
30. Experimental 18	17.6	22,600	4
31. DeKalb XL78	17.4	21,700	9
32. Experimental 9	17.4	25,500	10
33. Gutwein 92	17.3	21,700	1
34. Taylor-Evans 6968	17.1	23,000	4
35. Todd M90	16.9	16,800	4
36. Experimental 13	16.8	18,300	3
37. Experimental 14	16.4	24,100	5
38. Experimental 10	16.3	19,300	5
39. Experimental 12	16.1	20,300	7
40. PAG SX 494	15.9	22,900	9
41. Reid's Yellow Dent	13.9	20,900	11

$LSD_{.05}$ 4.4 Tons

C.V. 16.7

Effects of Sewage Sludge and Fertilizer Application on the Yields and Chemical Composition of Corn and Soybeans

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Purpose and Objectives

Increased environmental awareness by citizens and government is demanding that municipal waste disposal be done by safe procedures. A potential benefit to crop production has been proposed by many and much of the sewage sludges may be recycled onto agricultural land. The amounts of sewage sludge which can be safely and profitably applied to agricultural land are limited by such things as the nitrogen and heavy metal content of the sludge, the type of crop to be grown, the intended use of that crop, and the soil itself.

The objectives of this study were: (1) to look at yields of corn and soybeans as affected by rates of sludge applied to field plots; (2) to determine heavy metal uptake of these crops; and (3) to look at changes in the soil as a result of sludge application. This report deals with plant responses four years following sludge application.

Procedure

In the spring of 1972, digested sewage sludge from Washington, D. C. was applied to a Sassafras silt loam soil at rates of 0, 25, 50, and 100 dry tons per acre in strips 25 feet wide and 140 feet long. The area was divided in half at right angles to the sludge strip with corn being planted in one half and soybeans in the other half each year since 1972. Within each crop half, the area was divided into three blocks and fertilizer treatments were assigned at random within each block. Soybean fertilizer treatments were no fertilizer (F1) and 80 lbs. each of P_2O_5 and K_2O (F2);

corn fertilization was the same except that nitrogen (160 lbs N/A) was applied to the fertilized non-sludged plots in 1972-74. In 1975 and 1976, nitrogen was added to all of the fertilized corn plots. By the spring of 1975, soil pH had fallen and 3000 lbs. of high calcium lime were uniformly applied to all plots during final seedbed preparation prior to seeding the 1975 crops (See 1975 report). In the spring of 1976, pH values were still low so one ton of high calcium lime was applied and plowed down. A second ton was applied and worked into the surface before seeding.

Whole corn plant samples were taken at approximately the 12-leaf stage, ear leaf samples at silking, plus grain and fodder samples at grain harvest. Soybean leaves were sampled at mid-bloom and beans were saved for analyses at harvest. Grain and silage yield per acre were determined for corn and bean yields for the soybeans.

Results

Corn silage yields varied from 6.0 tons/acre with no sludge or fertilizer to 23.2 for 100 tons of sludge in 1972 plus annual fertilization (Table 1). Plots sludged with 50 tons without annual fertilizer applications had similar yields to non-sludged plots with annual fertilizer applications. Fertilizer application significantly increased silage yields at all but the 50-ton rate; grain yields did not follow the same pattern. There were no statistical differences among the 50- and 100-ton sludge treatments. However, the grain yields for plots within these two sludge rates were statistically higher than for all others. Fertilizer application at the 0 and 25-ton sludge rates increased grain yields. The 25-ton sludge-no fertilizer treatment produced significantly less grain than the unsludged plot with annual fertilization. Soybean yields were

significantly higher at the two high sludge rates but there was no fertilizer effect at any sludge rate. Only small yield differences existed between the 0 and 25-ton sludge rate.

Soil samples taken in May, 1976 just before the corn and soybeans were planted revealed low pH values, especially at the high sludge rates with fertilizer on corn (Table 2 and 3). Two tons of lime were applied and worked into the plow layer before planting. The phosphate, zinc, and copper levels in the top six inches of soil were high and increased with sludge rates; except for pH values, only small differences existed between the corn and soybean plots.

Zinc concentrations in both corn silage and grain were increased with increased sludge rates (Table 4). The values for silage were considerably higher. The application of lime in 1975 and 1976 resulted in marked decreases in Zn uptake by the plant.

Cadmium concentration in both silage and grain followed a similar pattern to that found with zinc. The application of lime reduced the cadmium concentration by half at the high sludge rates (Table 5).

The cadmium level of the soybeans increased with increased sludge rates (Table 6). When lime was added, the uptake of cadmium by the plant decreased. The actual values for the soybeans were generally lower than for corn grain.

Summary

1. After four years yields, corn silage, corn grain and soybeans at the 50 and 100-ton sludge rates without annual fertilization were significantly higher than those obtained from unsludged plots with annual fertilizer application.

2. The pH values of the high sludge plots continued to be low even

after lime application.

3. The phosphate level in all sludged plots continued to remain high.

4. Plant uptake of both zinc and cadmium was decreased with lime applications, but was significantly increased by increasing rates of sludge.

Table 1. Corn and soybean yields as affected by sewage sludge and fertilizer application, 1976.

Treatment		Corn		
Sludge[1/] T/A	Fertilizer[2/] Lbs/A	Silage T/A	Grain Bu/A	Soybeans Bu/A
0	F1	6.0 e[3/]	1.4 e	23.8 de
	F2	15.1 d	76.1 c	23.3 e
25	F1	13.3 d	61.4 d	26.6 cd
	F2	17.9 c	86.0 b	26.8 c
50	F1	19.7 bc	107.0 a	33.4 ab
	F2	21.4 ab	109.3 a	32.5 ab
100	F1	21.0 b	110.4 a	34.2 a
	F2	23.2 a	115.7 a	31.6 b

1/ Sludge applied in spring of 1972

2/ F1 = No fertilizer
F2 = Corn 160-80-80 lbs. N-P_2O_5- K_2O
= Soybeans 0-80-80 lbs. N-P_2O_5 - K_2O

3/ Values in each column followed by the same letter are from the same statistical population (p = 0.05)

Table 2. Nutrients analysis and pH of sludge amended soil from corn plots at the Plant Research Farm, May, 1976

Sludge Rate (T/A)	Depth (inches)	pH (1:1)	Mg	P_2O_5	K_2O	Zn	Cu
			lb/A				
		0 Fertilizer[1/]					
0	0-6	6.2	225	177	137	3.2	1.3
	6-12	5.8	162	20	124		
25	0-6	5.8	237	390	98	63	24
	6-12	6.1	198	32	101		
50	0-6	5.8	245	667	93	163	59
	6-12	5.8	182	50	115		
100	0-6	5.7	285	840	137	261	85
	6-12	5.7	169	105	145		
		+ Fertilizer[2/]					
0	0-6	5.9	232	222	174	5.6	2.2
	6-12	5.6	154	28	129		
25	0-6	5.9	259	430	128	63	23
	6-12	6.2	195	30	120		
50	0-6	5.8	251	690	141	147	52
	6-12	5.5	129	53	146		
100	0-6	5.7	301	868	160	265	80
	6-12	5.5	165	72	159		

1/ No fertilizer applied

2/ 160-80-80 lbs $N-P_2O_5-K_2O$

Table 3. Nutrients analysis and pH of sludge amended soil from soybean plots at the Plant Research Farm, May, 1976

Sludge Rate (T/A)	Depth (inches)	pH (1:1)	Mg	P_2O_5	K_2O	Zn	Cu
			lb/A				
		0 Fertilizer[1/]					
0	0-6	6.5	273	208	159	5.5	2.1
	6-12	5.9	186	13	130		
25	0-6	5.9	214	467	122	78	28
	6-12	5.9	162	37	149		
50	0-6	5.8	277	705	118	195	65
	6-12	5.8	197	72	136		
100	0-6	5.8	298	873	144	329	96
	6-12	5.7	179	110	208		
		+ Fertilizer[2/]					
0	0-6	6.3	244	262	195	7.8	3.1
	6-12	6.3	207	18	136		
25	0-6	5.8	235	640	178	97	35
	6-12	5.6	138	110	155		
50	0-6	5.8	284	755	156	195	63
	6-12	5.9	177	37	111		
100	0-6	5.7	295	835	155	285	91
	6-12	5.7	160	210	168		

1/ No fertilizer applied.

2/ 0-80-80 lbs N-P_2O_5 - K_2O

Table 4. Zinc concentration in corn silage and grain as affected by sludge rate, fertilization, and lime.

Sludge[1] Tons/A	Fertilizer[2]	Crop Sample	ppm Zinc 1974	1975[3]	1976[4]
0	F1	Silage	24 c[5]	28 c	48 bc
	F2		35 c	28 c	17 c
25	F1		131 b	95 b	51 bc
	F2		120 b	83 b	44 c
50	F1		218 a	172 a	105 a
	F2		179 ab	132 ab	91 ab
100	F1		289 a	123 b	133 a
	F2		268 a	120 b	123 a
0	F1	Grain	23 d	15 e	20 cd
	F2		22 d	17 de	17 d
25	F1		39 c	21 cd	21 cd
	F2		34 c	23 bc	22 bc
50	F1		50 b	24 abc	24 bc
	F2		49 b	24 abc	27 ab
100	F1		60 a	28 a	25 bc
	F2		60 a	27 ab	30 a

1/ Blue Plains digested sludge applied April, 1972

2/ Corn F1 = No fertilizer
F2 = 160-80-80 lbs. N-P_2O_5-K_2O (in 1974 N applied only to zero sludge).
Soybeans F1 = No fertilizer
F2 = 0-80-80 lbs. N-P_2O_5 -K_2O

3/ 3000 lbs. lime applied June, 1975 before crops were seeded.

4/ 4000 lbs. lime applied June, 1976 before crops were seeded.

5/ Values within each column for each plant sample followed by the same letter are from the same statistical population (p= 0.05).

Table 5. Cadmium concentration in corn silage and grain as affected by sludge rate, fertilization, and lime.

Sludge[1] Tons/A	Fertilizer[2]	Crop Sample	ppm Cadmium 1974	1975[3]	1976[4]
0	F1	Silage	0.61 d[5]	0.48 d	0.51 b
	F2		0.86 d	0.46 d	0.21 b
25	F1		3.16 bc	1.42 bc	0.54 b
	F2		3.00 c	1.15 c	0.83 b
50	F1		4.59 ab	2.24 a	1.68 a
	F2		4.08 ab	1.67 b	2.04 a
100	F1		3.95 ab	1.47 bc	2.08 a
	F2		5.33 a	1.57 b	2.28 a
0	F1	Grain	0.07 d	0.06 e	0.08 e
	F2		0.12 d	0.20 d	0.09 e
25	F1		0.39 c	0.30 c	0.22 d
	F2		0.41 c	0.38 b	0.26 cd
50	F1		0.58 b	0.38 b	0.28 cd
	F2		0.59 b	0.41 ab	0.44 ab
100	F1		0.68 a	0.44 a	0.37 bc
	F2		0.68 a	0.41 ab	0.52 a

1/ Blue Plains digested sludge applied April, 1972

2/ Corn F1 = No fertilizer
F2 = 160-80-80 lbs. N-P_2O_5-K_2O (in 1974 N applied only to zero sludge).
Soybeans F1 = No fertilizer
F2 = 0-80-80 lbs. N-P_2O_5 - K_2O

3/ 3000 lbs. lime applied June, 1975 before crops were seeded.

4/ 4000 lbs. lime applied June, 1976 before crops were seeded.

5/ Values within each column for each plant sample followed by the same letter are from the same statistical population (p = 0.05).

Table 6. Cadmium concentration of the soybean bean as affected by sludge rate, fertilization, and lime.

Sludge[1/] Tons/A	Fertilizer[2/]	ppm Cadmium 1974	1975[3/]	1976[4/]
0	F1	0.05 e[5/]	0.33 b	0.02 c
	F2	0.09 de	0.05 c	0.04 bc
25	F1	0.12 cde	0.62 a	0.07 abc
	F2	0.15 bcd	0.11 c	0.05 abc
50	F1	0.15 bcd	0.18 bc	0.07 ab
	F2	0.19 abc	0.15 bc	0.07 ab
100	F1	0.23 ab	0.20 bc	0.09 a
	F2	0.26 a	0.19 bc	.09 a

1/ Blue Plains digested sludge applied April, 1972

2/ F1 = 0-80-80 lbs. $N-P_2O_5-K_2O$

3/ 3000 lbs. lime applied June, 1975 before seeding.

4/ 4000 lbs. lime applied June, 1976 before seeding.

5/ Values within each year followed by the same letter are from the same statistical population (p=0.05).

Pasture Improvement with Sod-Seeding

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Purpose and Objectives

Beef consumption in the United States and other developed countries continues to increase. From 1952 to 1972, per capita beef consumption in the United States has gone from 62 to 116 pounds. With increasing world demands on feed grains, more and more of the feed for this increasing beef industry must come from forages. There are, currently, several million acres of land in Maryland and the Northeast which are idle with respect to agriculture production. Much of this idle land can be used to produce high yields of quality forages; also because of steep terrain and other limiting factors, the most effective use of many of these idle acres appears to be grazing. These acres can be used to raise dairy replacement females, feed out dairy steers for beef, or to increase beef cattle operations *per se*. Development of efficient pasture systems is the key to economical use of land awaiting the land speculator, or land that is too steep or otherwise unsuited for intensive crop production. The objective of this study was to evaluate sod-seeded pastures for the growth of dairy steers and replacement heifers.

Procedure

An orchardgrass pasture, taken out of production during the mid-1960's, was allowed to revert to a cover of largely bluegrass, herbaceous weeds, and woody brush species. Soils were variable with most classified as Sassafras sandy loam; the remainder were classified as Christiana silt loam. During the summer of 1974, the large woody species were removed and the area was cut with a bush hog rotary mower. During September, 1974, the area was divided into 20 three-quarter acre paddocks. These paddocks were divided into two replications and within each replication three sets of three

paddocks each, having comparable soil and vegetative cover, were grouped. Three pasture treatments were assigned at random within each of these uniform paddock groups. These pasture treatments were (1) weed and brush removed plus 350 pounds of an 0-15-30 fertilizer, (2) weeds and brush removed, fertilization, and sod-seeding to alternate rows of a red clover-ladino clover mixture and 'Penngift' crownvetch, and (3) same as treatment two with "Spreader" alfalfa rather than 'Penngift' crownvetch. The legume seedings were made with a Zip seeder equipped with a band seeding attachment to spray a 4 to 5 inch band of paraquat over each row as the legumes were seeded.

Two dairy heifers, two light dairy steers, and one heavy dairy steer (tester from 1975) were used as testers on each treatment. The heavy steer remained on the pastures only through the flush of spring growth. Light steer grazers were added as needed to maintain uniform grazing pressure among treatments. Pastures were grazed in a three-paddock rotational system with animals weighed each time they were moved to a new pasture; this varied from 6 to 20 days. Grazing started 20 April and ended 15 September. Animal condition scores were determined for each test animal at the start and end of the grazing season.

Pastures were clipped following grazing whenever utilization was not uniform or whenever weed invasion indicated a need. If one treatment in a cycle required clipping then all treatments were clipped for the sake of uniformity.

Results

Sod-seeded legumes increased average daily gains of all three types of test animals. The gains for both light and heavy steers were significantly higher on the crownvetch and alfalfa pastures than on the check.

With the heifers, crownvetch was significantly higher than for the check while this was not true for the alfalfa pastures (Table 1). As was the case in 1975, differences between crownvetch and alfalfa were due mainly to better red clover stands, even though there was more crownvetch than alfalfa in most paddocks. The heavy steers had been on a maintenance ration during the winter so were thin at the start of grazing; this is reflected in the relatively high rates of gain.

Liveweight gains per acre are shown in Table 2. The relatively larger gains for the light steers on crownvetch and alfalfa are primarily a reflection of higher stocking rates on these pastures. When considering liveweight gain per acre, the superiority of sod-seeded crownvetch or alfalfa pastures over the check pasture was even more pronounced than for average daily gain.

The greatest advantage of the sod-seeded pastures appeared to be in increased carrying capacity (Table 3). During the early part of the grazing season insufficient grazers were available and one of the paddocks of each treatment was skipped in the grazing cycle and the material was harvested as hay (Table 3). While rather large yield differences were found, they were not statistically different. This does point out, however, that one of the real advantages of the sod-seeded treatment was increased forage production in addition to improved quality with the added legume.

Forage quality as well as forage quantity must be used in evaluating any pasture treatment. In addition to rate and total gain per acre, the condition of the grazing animal can be used to evaluate pastures; these data are presented in Table 4. Animals were assigned at random to individual pasture treatments within each replication so that animal condition at the start of the season was not influenced by pasture treatment. The

change in animal condition is probably the best measure of pasture effects. In most cases animal condition on the sod-seeded pastures improved as the season progressed. This was not true on the check pastures where animal condition generally declined, except for the heavy steers. These results are a reflection of both quantity and quality of forage.

Summary

Average daily gains were increased when sod-seeded legumes were present. Because of increased forage growth, the sod-seeded pastures were able to carry more animals. Liveweight gain of all three types of animals was increased with sod-seeding. The total liveweight gain on the crownvetch pastures was almost double that of the check pastures. Animal condition improved with the addition of sod-seeded legumes.

Table 1. Average pounds gain per day of three dairy animal types as affected by pasture treatment.

Pasture Treatment	Heavy[1/] Steers	Light[2/] Steers	Replacement[2/] Heifers
Check	2.52 b[3/]	0.94 b	1.34 b
Crownvetch	3.07 a	1.76 a	1.81 a
Alfalfa	3.66 a	1.50 a	1.52 ab

1/ Average of two steers per treatment
2/ Average of four steers or heifers per treatment
3/ Values in each column followed by the same letter are from the same statistical population (P = 0.05)

Table 2. Pounds of liveweight gain per acre of three dairy animal types as affected by pasture treatment.

Pasture Treatment	Heavy[1/] Steers	Light[2/] Steers	Replacement[2/] Heifers
Check	34.9 b	82.5 b	92.2 c
Crownvetch	59.3 a	199.2 a	127.2 a
Alfalfa	58.1 a	180.3 a	118.2 b

1/ Average of two steers per treatment
2/ Average of four steers or heifers per treatment
3/ Values in each column followed by the same letter are from the same statistical population (P = 0.05)

Table 3. Average pasture carrying capacity for the season and forage yields when forage in one grazing cycle got ahead of the animals.

Pasture Treatment	Pasture Carrying Capacity[1/] (700-lb A.U./A)	Forage Yields[2/] Tons/Acre
Check	2.66 c[3/]	0.10 a
Crownvetch	4.37 a	0.43 a
Alfalfa	4.08 b	0.26 a

1/ Based on totals of heavy steers, light steers, and heifers.
2/ Based on three 30-ft. yield strips in one paddock of each replication.
3/ Values in each column followed by the same letter are from the same statistical population (P = 0.05).

Table 4. Animal condition as affected by pasture treatment, 1976.

Pasture Treatment	Type of Animal	Animal Condition[1/] Spring	Fall	Change
Check	Heavy steers[2/][3/]	2.75	3.32	+ 0.56
	Light Steers[2/]	2.98	2.44	- 0.54
	Heifers[2/]	2.72	2.64	- 0.08
Crownvetch	Heavy steers[2/][3/]	1.58	3.10	+ 1.49
	Light steers[2/]	3.16	3.42	+ 0.26
	Heifers[3/]	3.27	3.44	+ 1.75
Alfalfa	Heavy steers[2/][3/]	2.82	3.65	+ 0.83
	Light steers[2/]	3.03	3.03	0.00
	Heifers[3/]	2.85	3.41	+ 0.56

1/ 1 = poor; 2 = fair; 3 = good; 4 = very good
2/ Averages of two animals independently rated by four individuals
3/ Averages of four animals independently rated by four individuals

Extractable Zinc Levels in an Anaerobic Soil Amended with Sludge

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Purpose and Objectives

The extractability of Zn from sewage sludge amended soils has been shown to decrease when the soil is subjected to anaerobic conditions. Previous research has indicated that Zn extractability can be significantly changed within two days of submersion. This study was designed to determine the effects of soil oxidation-reduction potential (Eh), type of extractant, and soil pretreatment on the extractability of Zn from a sludge amended soil incubated under anaerobic conditions.

Procedures

A Pocomoke sandy loam was used in this study (Table 1). This soil naturally occurs in an area of alternate wetting and drying. Lyophilized, digested sewage sludge was added to 20g of soil at rates equivalent to 0, 25, 50 and 100 mT/ha (Table 2). The soil and sludge were thoroughly mixed and submerged in 30 ml distilled, demineralized water. The samples were incubated under N_2 to maintain anaerobic conditions. Incubation was conducted for 0.0, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0 and 32.0 days. At the end of each period, samples were collected and the Eh measured. One half of the samples were extracted as collected. The remaining samples were further subdivided to allow extraction with both double acid extractant (0.05 N HCl + 0.025 N H_2SO_4) and DTPA (0.005 M DTPA, 0.1 M TEA, and 0.01 M $CaCl_2$ adjusted to pH 7.3).

Results

Values for Eh and pH at the 50 mT/ha application rate are presented in Table 3. These data are typical of the data for all sludge loading rates. The Eh of the system showed a decreasing trend with time until about 4.0 days. At this point the Eh appeared to stabilize at about 100 mV until the experiment was terminated at 32 days. This is the point at which iron is reduced. As $FeCl_3$ is used as the flocculating agent in Blue Plains sewage sludge, a relatively high level of iron would be expected. The pH of the system was observed to decrease throughout the experiment, with the exception of the final observation at 32 days. No explanation is readily available for this phenomenon.

The variation in extractable Zn with changing Eh is presented in Figure 1. Levels of extractable Zn were observed to decrease with decreasing Eh in the case of both DTPA and double acid extractants, and in samples extracted both moist and following freeze-drying. Higher values were obtained consistently in those samples dried prior to extraction. A greater difference was observed in those samples extracted with DTPA than with double acid, although the two DTPA treatments became more similar with decreasing Eh. In each case, double acid yielded higher levels of extractable Zn than did DTPA.

The change in Eh appears to account for a relatively large portion of the change in extractable Zn (49-80%). This response may be due to the adsorption of Zn on colloidal hydrous oxides of Fe formed in the sample with the decrease in Eh. This mechanism would partially explain the continued decrease in extractable Zn even though the Eh values reached a plateau. Formation of hydrous oxides of Fe would progress with the Eh holding relatively constant. These ferrous hydroxides may be oxidized during freeze-

drying, causing the release of Zn adsorbed to the surface of the gel. This could account for the increase in extractable Zn levels in samples dried prior to extraction. The decrease in extractable Zn with decreasing Eh in the dried samples could be the result of the collapse of the ferrous hydroxides, physically trapping the Zn.

Summary

Changes in oxidation-reduction potential have been shown to have a marked effect on the levels of extractable Zn in the soil. Samples extracted as collected were observed to yield lower levels of extractable Zn than those freeze dried prior to extraction. Greater effects due to moisture regime were observed with DTPA than the double acid extractant. In all cases double acid produced higher values than did DTPA.

Table 1. Characteristics of a Pocomoke sandy loam (Ap horizon)

pH		4.5
		-- % --
Texture		
sand		76
silt		19
clay		5
Organic carbon		2.5
		-- ug/g --
Double acid extractable	P	18.9
" " "	K	6.6
" " "	Ca	9.8
" " "	Mg	0.9
DTPA extractable	Zn	0.1
" "	Cu	0.1
" "	Ni	0.0
" "	Cd	0.0

Table 2. Characteristics of an anaerobically digested sewage sludge from the Blue Plains waste water treatment facility

	--- % ---
N	3.1
P	2.8
K	0.17
organic carbon	25.2
	-- ug/g --
Zn	1300
Cu	930
Cd	16
Ni	12

Table 3. Changes in oxidation-reduction potential and pH in a Pocomoke sandy loam amended with 50 dry mT sewage sludge/ha and incubated under nitrogen for 32 days

Time	Eh*	pH*
days	-- mV --	----- units -----
0.0	+ 353.0	7.5
0.5	+ 366.0	7.3
1.0	+ 382.4	6.9
2.0	+ 186.7	6.8
4.0	+ 98.0	6.7
8.0	+ 69.0	6.5
16.0	+ 117.7	6.3
32.0	+ 42.0	7.0

*Each value represents the average of 12 observations.

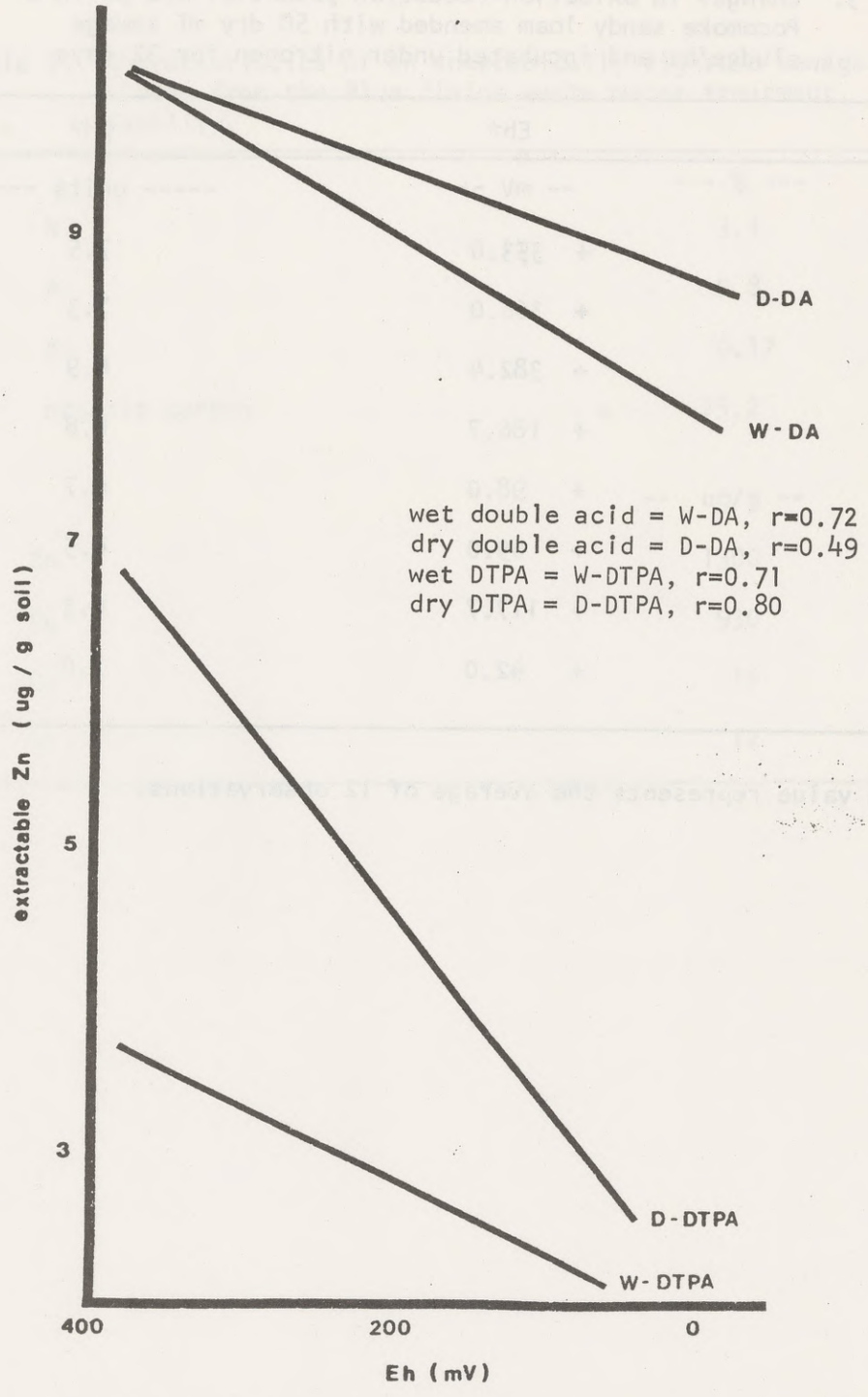

Figure 1. Relationship between Eh and extractable Zn in a Pocomoke sandy loam amended with digested sewage sludge at a rate equivalent to 50 dry mT/ha.

Tee Turf Research

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Purpose and Objectives

This experiment was designed to determine if increased traffic resistance can be obtained from a combination of management techniques and mixtures of grasses. More traffic resistant turf will benefit golf courses, athletic fields, tennis courts and schools.

The objectives were: (1) to evaluate the traffic bearing potential of zoysiagrass, bermudagrass, bluegrass and bentgrass alone and in two-way combinations and (2) to determine management factors that provide the greatest healing potential, quality and traffic resistance.

Procedures

In the early summer of 1973, stolons of 'Meyer' and 'Midwest' Zoysia and 'Tufcote' and 'Tifgreen' bermudagrass were planted at a rate of 4 bushels per 1,000 sq. ft. The plot design was a split-split plot with four replications. Individual plot size was 5' by 5'. Plots were located on a Chillum silt loam at the Plant Research Farm near College Park.

In September, 1973, the four warm season varieties were overseeded to a blend of five Kentucky bluegrass varieties and to 'Penncross' creeping bentgrass. Thus, warm season and bluegrass combinations were evaluated and compared to warm season and bentgrass combinations as well as to pure stands of each species. One-half of each replication received 1/8 inch of sand topdressing in May of 1974 and 3 applications in May, July and October of 1975.

Warm and cool season nitrogen fertilizer programs were initiated in May, 1974. These programs consisted of a 2 pound N/1000 sq. ft. application as ureaformaldehyde in late August. Additionally, the warm season program included

4-1 pound N applications/1000 sq. ft. as ammonium nitrate between early May and mid-August while the cool season program included 4-1 pound N applications/1000 sq. ft. after the bermuda goes dormant in October but before mid-March. Plots were mowed at 3/4 inches in the summer and 1 inch from September to early May.

Results

The results reported are for the third data year, 1976. Comparisons are made to the first and second year's results and most conclusions are tentative.

Under the warm season nitrogen program the cool season grasses died out and the bermudagrass dominated (Table 1). The bermudagrass in these plots had what was assumed to be spring dead spot, a management disease common to bermudagrass turf in the Northern half of the bermudagrass zone. The severity of this disease was significantly less under the topdressing treatment.

Due to the complete dominance by bermudagrass under the warm season N program, this N program was terminated in August. Plot areas receiving the warm season N program were then scalped, vertical mowed and overseeded to a mixture of perennial ryegrass varieties; the intent being to put this area under the winter N fertilizing program and thus study a bermuda-perennial ryegrass mixture.

Under the cool season nitrogen program a spring-fall fluctation of cool and warm season grass dominance has continued into 1976 (Table 2). The amplitude of the fluctations were greater for the 1976 season than for 1974, but similar to those in 1975. The overall composition of the plots in 1976 was very similar to that of 1975.

Winter annual weeds and some fall germinating perennials have become an increasing problem. As might be expected this was more of a problem under the summer N management which resulted in an almost complete loss

of cool season grasses. These cool season grasses could be expected to provide competition for winter annual weeds in a mixed stand of warm and cool season grasses. In May, 1975, there was estimated to be less than one percentage of the cover in weeds on the plots receiving winter N while the summer N plots had two percent. In May 1976, this had risen to 11 and 30 percent respectively.

In 1975 the first differences due to topdressing with sand were noticed and reported here. These differences were improved quality and increased percentages of creeping bentgrass. These differences continued into 1976 (Table 3).

Under the high N level used in this experiment invasion of neighboring plots by bermudagrass varieties has become an increasing problem even under the winter N fertilizing program. September is usually the month of maximum bermudagrass coverage; data from this month shows that bermuda had increased from 37% in 1974 to 60% coverage in September of 1976. The monocultures of Kentucky bluegrass and Penncross creeping bentgrass were least able to resist this invasion. The Meyer-bluegrass and Meyer-bentgrass combinations were best able to resist this invasion.

Summary

Under the warm season nitrogen program the cool season grasses were replaced with bermudagrass. Spring dead spot was observed in this grass and was found to be less severe under the topdressing treatment. The summer nitrogen program was terminated and these plots overseeded to perennial ryegrass. Winter annual weeds have become more of a problem under the summer nitrogen program than under the winter nitrogen program.

Table 1. Visual estimates of the percentage grass cover by each of four species for July data in three years from those plots receiving summer nitrogen. Values are averages over two topdressing treatments and 12 grass combinations.

	Years		
Grass species	1974	1975	1976
Bermudagrass	38C**	55B	78A
Zoysiagrass	8B	9B	12A
Creeping bentgrass	22B	28A	3C
Kentucky bluegrass	15A	8B	5C

** For each grass species, values followed by the same letter are from the same statistical population at the 1% level of significance according to the Duncan's Multiple Range Test.

Table 2. Visual estimates of the percentage grass cover by each of four species for May and September data in three years from those plots receiving winter nitrogen. Values are averages over two topdressing treatments and 12 grass combinations.

Grass species	May '74	Sept. '74	May '75	Sept. '75	May '76	Sept. '76
	% grass cover					
Bermudagrass	23	37	10	55	0	60
Zoysiagrass	5	14	3	13	1	10
Creeping bentgrass	35	30	45	15	44	5
Kentucky bluegrass	27	15	41	10	45	12

Table 3. Visual estimates of the percentage grass cover which was creeping bentgrass and quality for 1976 as affected by sand topdressing when on a winter nitrogen fertilizing program. Values are averages over 12 grass combinations.

Dates	Topdressed	Control	Topdressed	Control
	------- % bentgrass -------		------- quality ----------	
Feb. 76	+	+	2.8** 1/	1.9
Apr. 76	49**	29	6.3*	4.9
May 76	52*	35	7.0	6.2
June 76	51*	40	7.2*	6.5
July 76	45*	36	7.8*	7.3
Aug. 76	+	+	5.3	5.3
Sept. 76	7	3	5.9	5.8
Oct. 76	+	+	3.8	3.4
Nov. 76	+	+	2.8	2.8

**, * Within each month and each grass species, means followed by asterisks are statistically different than the control at the 0.01 and 0.05 level of probability.

\+ No data.

1/ Turfgrass quality rating made on a 0-9 scale with 9 equaling maximum turf quality and 0 equaling a dead, bare or completely weed covered plots. A rating of 6 or greater is considered acceptable.

Breeding of New Small Grain Varieties

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Purpose and Objectives

The development and release of new improved varieties for Maryland's farmers is the main goal of the small grain breeding program. The breeding of varieties is a continuous process for the improvement of agronomic characteristics and disease and insect resistance.

Results

The Maryland and Virginia Agricultural Experiment Stations have released a new high-yielding soft red winter wheat variety under the name Potomac (Va 66-54-6). This variety has had good yields, excellent test weight and good disease resistance.

Yield results over the past five years, 1971 to 1975, from 16 tests in Maryland showed Potomac to average approximately 10 bushels per acre better than Arthur and 6 bushels better than Blueboy (Table 1). In Virginia, Potomac has yielded approximately 4 bushels per acre better than Arthur and Blueboy for the last 8 years.

The plant matures three to five days later than Arthur and two days earlier than Redcoat. The mature plant is three to four inches taller than Arthur but shorter than Redcoat by several inches. Potomac plant height is irregular (Table 2).

Potomac wheat has good resistance to powdery mildew and leaf rust. The kernels are red, soft and ovate or egg shaped. The grain generally has excellent test weight, similar to Arthur. Test of the grain quality at the Soft Wheat Quality Laboratory at Wooster, Ohio, shows Potomac to produce a satisfactory flour protein level, good baking quality, and milling quality similar to Arthur.

Table 1. Yield (Bu/A) of Potomac Compared with Other Varieties at Several Locations in Maryland.

Variety	1971 (1)*	1972 (3)**	1973 (4)***	1974 (4)***	1975 (4)***	Average Last 2 yrs.	Average 5 yrs.
Potomac	82.1	59.1	32.5	55.6	50.8	53.2	56.0
Redcoat	69.7	52.9	17.9	44.5	37.6	41.1	44.5
Blueboy	74.3	55.6	27.8	49.1	44.6	46.9	50.3
Arthur	69.9	55.5	20.4	48.8	38.1	45.5	46.5

* College Park, Md.

** Average of College Park, Queenstown, Quantico, Md.

*** Average of Hagerstown, Clarksville, Queenstown, Quantico, Md.

Table 2. Comparative Performance of Potomac for Agronomic Characteristics Tested in Maryland, 1971-75.

Variety	Test Wt. lb/Bu	Heading Date	Lodging* %	Height Inches	Mildew* %	Leaf** Rust %
Potomac	59	May 16	36	43	17	12
Redcoat	58	May 18	25	46	21	0
Blueboy	55	May 15	15	41	44	25
Arthur	58	May 13	32	40	2	1

* 3 year average 1972-74

** 1974 severity

Performance of Barley Varieties and Breeding Lines in Maryland, 1976

J. W. Johnson
Department of Agronomy

Purpose and Objectives

Variety trials are necessary to evaluate new and presently grown varieties under Maryland's environmental conditions. Advanced breeding lines are also evaluated which have potential as a new variety. The information obtained from these trials provides a dependable guide for varietal selection.

Procedures

In 1976 performance trials were conducted at four locations with varying soil types. Two of these locations are on the Eastern Shore - Queenstown on a Mattapex silt loam and Quantico on a Galestown sandy loam. The other two locations are west of the Bay at Clarksville on a Manor silt loam and Hagerstown on a Hagerstown loam.

Four replications of a randomized complete block design were used at each location. Each plot consisted of two rows, 10 feet long and 1 foot apart. Management practices were used in accordance with those normally accepted for the production of barley. Fourteen standard varieties and four advanced breeding lines were evaluated at all locations.

Results

Barley results are reported in Table 1. The average performance of the varieties revealed that Volbar and Rapidan were the highest yielding varieties with 90 and 85 bushels per acre, respectively. Barsoy yielded only 61 bushels per acre. Henry, Surry, and Monroe are promising new barley varieties released by the Virginia Agricultural Experiment Station in 1976. Three advanced

breeding lines, Va 71-44-26, Md 45-286-64, and Md 45-44-11 illustrate the progress in the small grain breeding program. Test weights were exceptionally high throughout the state.

Summary

Rapidan is presently the popular variety grown in the state. Barsoy yielded similar to Rapidan west of the Bay; however, it is no longer a top yielder on the Eastern Shore. Several advanced breeding lines have been produced with excellent disease and lodging resistance.

Table 1. Average performance of barley for several characteristics in Maryland,+ 1976.

Entry	Yield Bu/A	Test Wt. Lbs/Bu	Date Headed	Height Inches	Percent Lodging
Volbar	89.5	48	May 2	38	15
Rapidan	84.7	46	April 29	33	40
*Va 71-44-26	82.0	47	May 2	34	14
*Md 45-286-64	78.1	48	April 27	34	10
*Md 45-448-11	76.9	47	May 2	32	15
Kamiak	76.3	48	May 2	33	23
Surry	75.1	46	April 28	33	14
Monroe	74.6	47	May 3	32	13
Pennrad	74.2	47	May 2	38	21
Henry	72.6	47	April 30	33	10
Hanover	70.6	47	April 30	35	25
Jefferson	67.7	47	May 3	35	11
Knob	66.5	47	April 27	32	16
Harrison	65.0	49	May 3	33	8
Md 45-242-10	63.8	48	April 24	38	32
Nebar	61.3	49	May 3	35	29
Barsoy	61.1	50	April 20	31	33

*Advanced breeding line.

+Average of Queenstown, Quantico, Clarksville and Hagerstown.

Performance of Wheat Varieties and Breeding Lines in Maryland, 1976

J. W. Johnson
Department of Agronomy

Purpose and Objectives

Variety trials are necessary to evaluate new and presently grown varieties under Maryland's environmental conditions. Advanced breeding lines are also evaluated which have potential as a new variety. The information obtained from these trials provides a dependable guide for varietal selection.

Procedures

In 1976 performance trials were conducted at four locations with varying soil types. Two of these locations are the Eastern Shore - Queenstown on a Mattapex silt loam and Quantico on a Galestown sandy loam. The other two locations are west of the Bay at Clarksville on a Manor silt loam and Hagerstown on a Hagerstown loam.

Four replications of a randomized complete block design were used at each location. Each plot consisted of two rows, 10 feet long and 1 foot apart. Management practices were used in accordance with those normally accepted for the production of wheat. Thirteen standard varieties and six advanced breeding lines were evaluated at all locations.

Results

The average performance of the wheat varieties at all locations is presented in Table 1. Wheat yields were high even though hot dry conditions prevailed at pollination. Diseases were also not severe this year. Arthur and Potomac yielded the highest of the standard varieties with 58 and 56 bushels per acre, respectively. The Maryland and Virginia advanced breeding lines, Md 55-36-45, Md 55-114-03, Va 70-52-22, and Va 71-54-147 looked

promising. Yield results for the last three years showed that Potomac averaged 8 bushels per acre better than Arthur.

Summary

Potomac is a new release from the Maryland and Virginia Agricultural Experiment Stations. Yield results in Maryland show Potomac as a high-yielding variety. The performances of the advanced breeding lines illustrate the potential of superior varieties.

Table 1. Average performance of wheat varieties for several characteristics in Maryland,+ 1976.

Entry	Yield Bu/A	Test Wt. Lbs/Bu	Date Headed	Height Inches	Percent Lodging
*Md 55-36-45	63.8	58	May 12	39	9
*Va 70-52-22	61.9	57	May 13	34	3
*Md 55-114-03	60.2	60	May 8	37	21
*Va 71-54-147	59.1	59	May 11	32	5
Arthur	58.3	60	May 7	36	10
*Va 72-54-14	58.2	58	May 10	35	15
Potomac	56.1	60	May 13	39	13
*Md 55-183-04	54.6	59	May 15	36	6
Oasis	54.3	60	May 9	35	17
Coker 68-15	54.2	61	May 5	32	0
Abe	53.6	60	May 7	34	13
McNair 4823	53.3	60	May 12	34	2
Blueboy	51.7	57	May 13	35	8
Arthur 71	50.9	60	May 9	36	14
Redcoat	50.5	60	May 15	42	3
McNair 1813	48.4	60	May 9	33	3
Doublecrop	43.8	60	May 7	35	14

*Advanced breeding line

+Average of Queenstown, Quantico, Clarksville and Hagerstown.

Performance of Soybean Advanced Breeding Lines in Maryland, 1976

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Purpose and Objectives

The identification of superior breeding lines requires extensive testing to determine agronomic performance of each genotype. Advanced breeding lines must be tested at least three years not only in local tests, but also in regional tests, before a line is released as a new variety. The objective of this test is to provide performance data of several breeding lines to determine which should be advanced to regional tests. The agronomic performance of each breeding line will be compared to the standard varieties included in the tests.

Procedures

A total of 20 advanced breeding lines was grown in two tests. Entries were assigned to the group IV-S or group V test based upon their maturity. Standard varieties grown in the maturity group IV-S test were Cutler 71 and Kent while Essex and York were the standard varieties grown in the maturity group V test.

The group IV-S test was grown at Quantico and the group V test was grown at Quantico and Queenstown. Each entry was evaluated in a four-row plot which was 20 feet long. A row spacing of 30 inches was used at both locations. Yield was determined on a 16-foot section from the center two rows of each plot. Two replications of a randomized complete block design were used for each test. Recommended cultural practices were followed in each test. The tests were planted at Quantico on May 21 and at Queenstown on May 25.

Results

The average performance of entries grown in the maturity group IV-S test at Quantico is shown in Table 1. The yields of Md72-8402 and Md72-8412 were impressive. However, the yields of the standard varieties were reduced due to dry weather. The average yield of all entries was less than 27 bushels/acre.

The average yield of the entries in the group V test was much higher than the group IV-S test as shown in Table 2. None of the breeding lines yielded higher than Essex.

Summary

Only Md72-8412 from the group IV-S test was selected for additional testing in regional yield tests.

Table 1. Average performance of maturity group IV-S entries grown at Quantico, 1976.

Entry	Yield Bu/A	Rank	Maturity Mo-Day	Lodging Score 1/	Height In	Seed Quality 2/	Seed Size g/100 Seeds
Md72-8689	21.5	10	10-13	1.0	28	4.0	20.0
Md72-8626	21.4	11	10-10	1.0	30	3.0	16.7
Md72-8412	36.2	2	10-15	2.0	43	2.5	18.2
Md72-8638	31.0	4	10-15	2.0	37	2.0	16.5
Md72-8683	32.0	3	10-12	2.0	35	2.0	16.0
Md72-8402	36.3	1	10-16	3.0	40	2.0	17.4
Md72-8771	23.7	8	10-13	1.0	34	2.0	18.0
Md72-8410	26.3	6	10-13	2.0	33	3.0	21.2
Md72-86107	23.4	9	10-16	2.0	29	3.0	17.6
Md72-8605	26.8	5	10-14	2.0	32	2.0	17.0
Kent	25.7	7	10-2	2.0	27	3.5	20.8
Cutler 71	18.7	12	10-2	1.0	21	4.0	20.5
Mean	26.9						
L.S.D. (0.05)	6.8						
C.V. (%)	11.5						

1/ Lodging Score: 1 = all plants erect; 5 = all plants down

2/ Seed Quality: 1 = excellent (no moldy, cracked, or wrinkled seeds); 5 = poor.
Soil Type: Galestown loamy sand

Table 2. Average performance of maturity group V entries grown at Quantico and Queenstown, 1976.

Entry	Yield Bu/A	Rank	Maturity Mo-Day	Lodging Score 1/	Height In	Seed Quality 2/	Seed Size g/100 Seeds
Md72-86109	36.9	6	10-17	2.3	48	2.2	16.7
Md72-8704	36.5	8	10-16	3.0	44	2.5	15.7
Md72-8537	35.7	11	10-15	3.0	42	2.8	15.1
Md72-8688	37.8	5	10-12	2.0	32	2.2	16.4
Md72-8655	36.0	10	10-15	2.3	47	2.0	17.0
Md72-8437	38.3	3	10-11	2.3	39	2.5	19.2
Md72-86124	38.1	4	10-15	2.7	49	2.0	15.6
Md72-8482	35.6	12	10-18	3.0	38	2.0	18.1
Md72-8601	36.2	9	10-14	2.0	46	2.2	16.5
Md72-8644	38.9	2	10-15	2.3	48	2.0	15.8
Essex	41.4	1	10-17	2.0	31	2.0	14.5
York	36.7	7	10-17	1.7	32	2.0	19.3
Mean	37.3						
L.S.D. (0.05)	N.S.						
C.V. (%)	9.2						

1/ Lodging Score: 1 = all plants erect; 5 = all plants down

2/ Seed Quality: 1 = excellent (no moldy, cracked, or wrinkled seeds); 5 = poor.

Soil Type: Quantico = Galestown loamy sand Queenstown = Matapeake silt loam

Performance of Soybean Varieties and Breeding Lines in Maryland, 1976

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Purpose and Objectives

The variety tests provide Maryland soybean producers with information on agronomic performance of soybean varieties. Entries in the tests include public and private varieties that are available to Maryland farmers. Advanced breeding lines which have potential as new varieties are also evaluated in the tests.

Procedures

Varieties in maturity groups II - V are adapted to production in Maryland. Two tests were designed which included entries adapted to (1) Piedmont and Upper Eastern Shore and (2) Lower Eastern Shore, respectively. The Piedmont and Upper Eastern Shore tests were grown at Clarksville and Kennedyville, respectively. Entries in these tests consisted of 13 varieties and 11 advanced breeding lines. The Lower Eastern Shore tests were grown on two soil types at Queenstown and one soil type at Quantico. An additional test was planted June 10 at Quantico following the harvest of barley. Entries in the Lower Eastern Shore tests include 15 varieties and 9 advanced breeding lines.

Three replications of a randomized complete block design were used at each location. Each plot consisted of four rows spaced 30 inches apart and 20 feet long. Yields were determined on the center two rows of each plot which were end-trimmed to 16 feet. Plants were classified as mature when 95% of their pods were brown. The lodging score was obtained at maturity. Height was also obtained at maturity and was determined by measuring from the ground to the tip of the main stem. Seed quality was rated according

to the amount and degree of wrinkling, defective seed coats, and moldy or rotten seeds. Seed size was determined by the weight of 100 seeds.

Recommended cultural practices were followed in each test. The full season tests were planted on the following dates: Clarksville - June 9; Kennedyville - May 20; Quantico - May 21; and Queenstown - May 25.

Results

The average performance of entries grown in the Piedmont and Upper Eastern Shore tests is shown in Table 1. L21, an advanced breeding line from Illinois, was the highest yielding entry in the test. Recommended varieties for this area include Calland, Cutler, Delmar, Kent, and Williams. Dry weather reduced the yield of entries at Kennedyville and caused most entries to mature early.

The average performance of the entries grown in the Lower Eastern Shore full season tests is shown in Table 2. The two highest yielding entries in these tests are from the University's breeding program. Md71-407 is being considered for release as a variety. Dry weather also caused some entries to mature early in these tests. Recommended varieties for this area include Cutler, Delmar, Essex, Kent, Shore, Williams, and York.

Performance of the entries when planted after barley at Quantico is summarized in Table 3. A private variety, Asgrow 5305, was the highest yielding entry. The late maturing varieties generally yielded higher than early maturing varieties in this test.

Summary

The performance of several advanced breeding lines was encouraging. Md71-407 will be considered for release as a variety.

Table 1. Average performance of soybean entries grown at Clarksville on Chester silt loam and grown at Kennedyville on Matapeake silt loam, 1976.

Entry	Yield Bu/A	Rank	Maturity Mo-Day	Lodging Score 1/	Height In	Seed Quality 2/	Seed Size g/100 Seeds
Corsoy	27.7	19	9-18	1.8	32	2.2	14.8
Beeson	30.2	15	9-20	1.4	30	2.0	18.4
L70D6-16	31.6	8	9-20	2.0	36	2.2	17.3
C1508	31.0	14	9-22	1.0	36	2.0	15.6
Woodworth	32.7	6	9-23	1.2	38	2.0	14.1
Wayne	31.3	10	9-24	1.6	34	2.0	15.4
Calland	31.1	12.5	9-26	2.4	37	2.7	17.4
FFR444	27.2	20	9-26	2.0	36	2.0	14.4
L21	35.6	1	9-26	2.0	38	2.0	18.6
Cutler 71	34.1	2	9-30	2.5	40	2.0	16.8
L71L-554	33.2	4	9-30	2.5	38	2.0	16.4
Md70-2221	33.4	3	9-30	1.2	34	2.0	15.2
Williams	32.4	7	9-30	1.2	34	2.0	15.9
Essex	22.8	23	10-2	2.5	38	3.5	10.9
Pomona	31.1	12.5	10-2	1.8	38	2.0	16.8
Kent	33.0	5	10-4	1.8	36	2.0	16.5
Md71-703	31.4	9	10-4	1.5	37	2.0	17.0
V68-1242	29.5	18	10-6	2.0	32	1.8	19.0
Delmar	22.2	24	10-8	2.4	38	2.2	15.3
Md70-1212	30.0	16	10-8	2.5	40	2.2	16.2
Md71-407	31.2	11	10-8	1.6	36	2.0	13.8
S63-5328S	29.8	17	10-8	2.5	40	2.0	14.3
D66-5566	26.0	21	10-9	2.0	28	2.3	13.3
Columbus	24.9	22	10-10	2.2	34	2.2	14.2
Mean	30.2						
L.S.D. (0.05)	3.4						
C.V. (%)	11.7						

1/ Lodging Score: 1 = all plants erect; 5 = all plants down

2/ Seed Quality: 1 = excellent (no moldy, cracked, or wrinkled seeds); 5 = poor.

Table 2. Average performance of soybean entries grown at Queenstown on Mattapeake silt loam and Sassafras sandy loam and grown at Quantico on Galestown sandy loam, 1976.

Entry	Yield Bu/A	Rank	Maturity Mo-Day	Lodging Score 1/	Height In	Seed Quality 2/	Seed Size g/100 Seeds
Md71-407	39.3	2	9-20	1.6	35	2.3	16.3
Woodworth	33.1	18	9-24	1.6	32	3.0	16.6
FFR444	32.9	19	9-25	2.1	35	2.4	17.4
L21	35.6	10	9-25	2.0	37	2.3	19.7
Wayne	29.8	23	9-25	1.8	32	3.0	17.9
Cutler 71	34.0	14	9-26	2.2	37	2.6	19.1
Md70-2221	35.6	10	9-26	1.6	34	2.0	16.8
Williams	35.7	7.5	9-26	1.5	32	2.4	18.8
Wye	30.7	21	9-26	2.0	29	2.8	16.4
Delmar	31.5	20	9-27	2.2	37	2.0	16.2
D66-5566	38.2	4	9-30	1.3	26	2.0	15.8
Kent	33.5	16	9-30	1.6	34	2.3	18.0
Columbus	33.3	17	10-2	2.6	39	2.1	15.2
Md70-1428	38.8	3	10-2	1.3	40	2.3	18.0
Md70-8412	36.0	6	10-8	2.0	33	2.0	16.6
V68-1242	35.7	7.5	10-9	2.0	30	2.0	18.6
Md71-583	39.8	1	10-12	2.3	46	2.0	14.0
N70-1549	36.2	5	10-18	2.0	35	2.0	13.7
A5305	35.6	10	10-19	2.3	38	2.0	13.7
Essex	33.7	15	10-19	2.3	33	2.1	15.2
A5312	35.2	12	10-22	2.3	38	2.2	12.3
Shore	28.4	24	10-22	2.3	36	1.9	15.8
York	34.3	13	10-22	2.2	38	2.0	16.5
FFR556	29.9	22	10-25	2.3	45	2.0	15.3
Mean	34.5						
L.S.D. (0.05)	N.S.						
C.V. (%)	13.6						

1/ Lodging Score: 1 = all plants erect; 5 = all plants down

2/ Seed Quality: 1 = excellent (no moldy, cracked, or wrinkled seeds); 5 = poor.

Table 3. Performance of soybean entries planted after barley at Quantico, 1976.

Entry	Yield Bu/A	Rank	Maturity Group	Seed Quality 1/	Seed Size g/100 Seeds
Wayne	21.4	24	III	2.0	19.4
Williams	25.7	18	III	2.0	20.8
Woodworth	23.4	22	III	2.0	18.7
Columbus	34.0	6	IV	2.0	16.4
Cutler 71	22.2	23	IV	2.0	19.6
Delmar	31.0	10	IV	2.0	15.5
D66-5566	33.2	8	IV	2.0	15.4
FFR444	26.2	17	IV	2.0	18.1
Kent	28.9	13	IV	2.0	19.8
L21	24.9	20	IV	2.0	21.5
Md70-1428	31.7	9	IV	2.0	13.4
Md70-2221	27.8	15	IV	2.0	18.5
Md70-8412	34.4	5	IV	2.0	16.2
Md71-407	29.0	12	IV	2.0	17.2
V68-1242	27.4	16	IV	2.0	20.4
Wye	25.0	19	IV	3.0	15.9
A5305	36.2	1	V	2.0	13.9
A5312	30.1	11	V	2.0	12.5
Essex	34.9	4	V	2.0	13.2
FFR556	24.1	21	V	2.0	15.6
Md71-583	33.5	7	V	2.0	13.4
N70-1549	35.8	2	V	2.0	14.6
Shore	28.3	14	V	2.0	16.6
York	35.0	3	V	2.0	17.2
Mean	29.3				
L.S.D. (0.05)	5.4				
C.V. (%)	11.1				

1/ Seed Quality: 1 = excellent (no moldy, cracked, or wrinkled seeds); 5 = poor.

Soil Type: Galestown loamy sand

Extractability and Uptake by Corn of High Concentrations of Cd, Cu, Ni and Zn Applied to Different Soil Materials at Two pH Regimes

R. F. Korcak and D. S. Fanning

Purpose and Objectives

The application of sewage sludges to land has brought about many areas of concern. One question has been--are some soils better for sludge use than others? With respect to heavy metals the question might be phrased--"Do some soils react with the heavy metals to prevent them from being taken up by plants better than others?"

Since it has been suggested by other researchers that increasing soil pH, cation exchange capacity (CEC) and/or the contents of iron and other oxides may decrease heavy metal availability, several Maryland soils that varied in these properties were selected for comparison in a greenhouse study. The specific objectives were: (1) To observe the effects of soil type and pH on the extractability and uptake by corn (*Zea mays* L.) of high concentrations of Cd, Cu, Ni and Zn applied as metal salts or sewage sludge and (2) To monitor the rate at which Cd, Cu, Ni and Zn changed in availability with time in the metal salt or sewage sludge amended soils.

Procedure

Surface and subsurface samples of three "low" (Downer, Torhunto and Evesboro) and three "high" (Manor, Myersville and Collington) CEC Maryland soils were amended with metal salts equivalent to a Blue Plains (Washington, D.C.) sewage sludge that contained 20, 786, 68 and 2068 ppm of Cd, Cu, Ni and Zn, respectively. Metal salt additions were equivalent to 14, 56 and 224 dry mT/ha for the "low" CEC soils and 56, 224 and 896 dry mT/ha

for the "high" CEC soils. A separate 224 dry mT/ha sewage sludge treatment was applied to all soils. Pots containing 2.5 kg of soil were either limed to pH 6.5 or maintained at field pH (5.0 to 5.9). The soils were equilibrated after metal additions in the greenhouse for a period of thirty days. Corn was grown twice for 30 day periods; one month and one year after the equilibration period ended.

Pertinent soil properties of the soils used in study are presented in Table 1. Soil heavy metal availability was estimated by the DTPA extraction procedure of Norvell and Lindsay (Agronomy Abstracts 1969, p. 84). DTPA extractable metals were determined seven times over the 14 month duration of the experiment. The aerial portion of the corn plants was analyzed for metals using the dry ashing technique of Isaac and Johnson (1975).

Results

DTPA extractable metals. The relative order of metal extractability, expressed as a percent of the total metal applied, was Cd > Cu > Zn > Ni from the metal salt or sewage sludge amended soils. Two examples of metal extractability over time as influenced by treatment level, source of metal and liming are presented in Figures 1 and 2. Generally liming tended to decrease DTPA extractable Zn independent of soil type (e.g. Fig. 1) while the liming effect on DTPA extractable Cd was either not as great or nonexistent (Fig. 2).

Soil samples extracted after each corn harvest period (Sampling Times 3 and 7, Figs. 1 and 2) showed depressed levels of DTPA extractable Cu, Cd, Ni and Zn independent of treatment, soil or pH regime. It was proposed (Korcak, 1977) that this effect was due to a buildup of metals

in the roots which remained unextractable until the roots decomposed. The 224 dry mT/ha sewage sludge additions usually resulted in lower extractable metal levels than the corresponding 224 dry mT/ha metal salt equivalent treatment. This is a reflection of the lower extractability of the sludge borne metals.

The effect of time, 14 months, on metal extractability from the metal salt treatments was less than the effect of the initial contact period of the metal with the soil (Figs. 1 and 2). This assumes that all of the applied metal, the amounts of which are shown by the horizontal lines intersecting the y axis in Figs. 1 and 2, would have been extractable before contact with the soil. The extractable Cu and Cd levels from the sludged soils tended to increase slightly with time while extractable Ni and Zn attained initial maxima and decreased with time (Korcak, 1977).

DTPA extractable metals from soil samples taken 13 months after initiation of the experiment are presented in Table 2. Except for the Torhunta and Evesboro soils, the B horizons were better able to render the applied metals unextractable to the DTPA reagent than the corresponding A horizons.

Among all soils the Myersville B2t horizons gave significantly lower levels of DTPA extractable Cu and Cd than all other soils independent of pH regime (Table 2). DTPA Zn levels were significantly lower from the Myersville Ap and B2t horizons under limed conditions and from the Myersville B2t horizon under unlimed conditions than all other soils. DTPA extractable Ni levels were generally low for all limed soils and significantly lower from the unlimed Torhunta A1, Downer Ap and B2t, Manor B2 and Myersville B2t.

Correlation analyses were performed between the DTPA extractable metal values from the limed 56 or 224 mT/ha metal salt additions and various soil parameters. These soil parameters included: organic matter, percent clay, oxalate or citrate-dithionite extractable Fe, total soil Fe or Mn, double acid (0.05 N HCl, 0.025 N H_2SO_4) extractable Mn, CEC by NH_4^+ saturation, Ca or K exchange capacity and percent "vermiculite". CaEC, KEC and percent "vermiculite" were determined by the method of Coffman and Fanning (1974). The coefficients of determination (r^2 values) obtained are presented in Table 3. All of the r^2 values presented in Table 3 had negative r values indicating that as the level of a particular soil parameter increased the amount of DTPA extractable metal decreased.

DTPA extractable Ni was not significantly correlated with any of the soil parameters measured. Liming tended to decrease extractable Ni to very low levels for all soils (e.g. see Table 2). Therefore Ni was reverted to some form that was DTPA unextractable independent of soil type. DTPA Cu was significantly correlated at the limed 224 mT/ha level with percent clay, CEC, CaEC and percent "vermiculite" (Table 3). All of these parameters have a relationship to the exchange capacity of the soils. Notably KEC, which is related to exchange sites on soil components other than vermiculite, was not significantly correlated.

DTPA extractable Zn showed a highly significant (1%) correlation between the amounts extracted at the 224 mT/ha level and CEC (Table 3). This indicates that at high metal loads soils higher in CEC would be better ameliorators of applied Zn. Total Mn, dithionite-extractable Fe, KEC, and CaEC also produced significant correlations with DTPA extractable

Zn. The presence of significant correlations with total Mn and dithionite-extractable Fe may indicate that the oxides of these metals may play a role in Zn fixation into DTPA unavailable forms.

DTPA extractable Cd was highly associated (1% level) with total soil Fe and dithionite-citrate extractable Fe at the high application rate (Table 3). These high correlations indicate that crystalline Fe oxides may play an important role in ameliorating DTPA unextractable Cd since oxalate extractable Fe showed a poor correlation (oxalate extracts primarily amorphouse Fe oxides). A variety of other parameters were also correlated with DTPA extractable Cd indicating that for this element many simple correlations may prove useful in determining which soil(s) is (are) better able to render Cd unavailable.

Plant Data. Corn yields, from the plants grown on the soil materials treated with metal salts equivalent to 224 mT/ha of sludge, 13 months after initiation of the experiment, are presented in Table 4. Generally, the B horizon soils produced lower yields than the corresponding A horizon soils and the Evesboro and Torhunta B horizon soils gave significantly lower yields compared to all other soils.

Incipient metal toxicity levels in corn were estimated to occur at levels (in ug/g) greater than: 300 for Zn, 20 for Cu, 50 for Cd and 20 for Ni. These values, however, have limitations in that they are based on other literature dealing with single metal toxicity levels which do not consider interactions between metals.

Plant tissue metal concentrations from the corn plants grown after a 13 month soil "equilbration" at the 224 dry mT/ha (100 T/A) metal level are shown in Table 5. Inspection of Table 5 indicates that incipient Zn

toxicity was probably occurring on the unlimed Torhunta B2g, Evesboro Ap, Collington Ap and B2t, as well as on the limed Evesboro B2, soil materials. There were significant differences in tissue metal levels between soils. On a single element basis, only Zn levels were above the estimated incipient toxicity threshold level. Generally liming tended to reduce tissue concentrations of all metals. Under limed conditions, plant Cu and Ni levels were all low and within normal ranges. A better look at plant Zn and Cd levels can be gained by observing Cd/Zn ratios presented in Table 6.

Liming, with one exception, increased the Cd/Zn ratio for both the DTPA extractable metals and plant tissue concentrations. This is an undesirable situation, since Cd is considered a greater environment hazard than Zn. On this basis the soil(s) producing the lowest Cd/Zn ratios would be considered best suited to utilization of wastes high in the heavy metals. In comparing all soils, a better comparison can be made by looking only at the limed treatments, since following liming all soils had a similar pH ($\sim$6.5). Also the Evesboro B2 soil may not be a valid inclusion in such comparisons since it may have produced plants under a high ($>$300 ug/g) Zn stress. Considering these circumstances, the Manor soil would be considered the "best choice" for application of wastes for the metal concentrations used.

Conclusion

From plant metal uptake and DTPA extractable metal data obtained after an equilibration period of 13 months in the greenhouse using a variety of soils it was found that the Manor soil may be the "best choice" of the soils employed for applications of wastes containing equivalent metal levels.

There existed differences between all soils which may be overrided by pH. This is particularly true for extractable and plant uptake of Cu and Ni. Both Zn and Cd may be affected more by soil type than pH increases under the conditions of this experiment.

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Table 1. Pertinent characteristics of the soils employed in the study

Soil Series* and Horizon	Particle-Size Analysis			Organic Matter	Fe_o	Fe_d	Field pH (1:1 H_2O)	CEC	CaEC	KEC	% 'Vr'
	Sand	Silt	Clay								
	%							meq/100g			
Torhunta A1	76	19	5	3.84	.022	0.036	4.2	7.4	3.8	2.1	1.2
B2g	81	14	4	0.28	.022	0.018	4.6	3.0	1.9	1.2	0.5
Evesboro Ap	90	8	2	1.15	.064	0.280	5.4	2.2	1.4	0.7	0.4
B2	84	12	4	0.15	.056	0.217	5.8	1.2	2.0	0.5	1.0
Downer Ap	76	19	5	1.31	.079	0.336	4.9	3.9	3.2	1.8	0.9
B2t	63	23	14	0.36	.148	0.996	5.3	6.1	6.3	4.5	1.2
Collington Ap	77	16	7	1.10	.198	0.280	5.5	4.3	4.7	2.7	1.3
B2t	51	26	23	0.32	.650	0.778	4.9	13.2	13.4	9.0	2.9
Manor Ap	62	26	12	1.97	.096	1.466	5.3	7.2	5.3	4.2	0.7
B2	68	18	14	0.35	.121	1.779	5.6	7.4	6.7	5.2	1.0
Myersville Ap	26	58	16	2.50	.461	2.938	5.4	14.9	13.5	9.5	2.6
B2t	22	52	26	0.88	.420	3.908	5.9	18.2	27.5	10.8	10.8

*The Torhunta, Downer and Myersville soils are the more correct taxonomic names for the sites sampled that were originally mapped as Pocomoke, Sassafras and Fauquier, respectively.

**Texture based on the fractionation scheme of Kittrick and Hope (1963); organic matter estimated by the wet oxidation procedure employed by the Univ. of MD Soil Test Lab.; CEC by NH_4^+ saturation and Na^+ replacement; oxalate extractable Fe (Fe_o) by the procedure of Schwertmann (1964), dithionite-citrate extractable Fe (Fe_d) by the procedure of Fanning et al. (1970), and CaEC, KEC and % 'Vr' by the procedure of Coffman and Fanning (1974).

Table 2. DTPA extractable metals from the limed and unlimed soils receiving the metal salt equivalent of 224 dry mT/ha (100 T/A) sewage sludge and sampled 13 months after initiation of the greenhouse experiment. All values are averages of three determinations*

Soil-Horizon		Zinc		Copper		Nickel		Cadmium	
		Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
		ug/g							
Torhunta	A1	22g**	91c	16.2f	20.0e	0.2ef	1.2 def	1.45c	1.72bc
	B2g	49de	140a	19.1e	29.6b	0.4de	1.7cd	1.77a	1.95a
Evesboro	Ap	76b	126b	26.5b	29.3b	1.3b	3.1a	1.62b	1.77ab
	B2	88a	136ab	24.0cd	28.8b	1.2b	2.7ab	1.51bc	1.85b
Downer	Ap	61c	100c	23.4d	23.1d	0.2ef	1.0ef	1.63b	1.75b
	B2	50d	102c	19.7e	26.2c	0.0f	1.1def	1.29d	1.60cd
Collington	Ap	74b	100c	28.2a	31.0b	1.7a	2.7ab	1.56bc	1.53d
	B2t	38f	95c	16.2f	26.6c	0.1f	2.9a	0.97f	1.36e
Manor	Ap	45e	78d	24.7c	29.2b	0.5d	1.5de	1.14e	1.53d
	B2	39f	63e	13.0g	17.7f	0.1f	0.6f	0.62gh	0.89f
Myersville	Ap	23g	56e	19.6e	29.2b	0.8c	2.2cb	0.74g	1.00f
	B2t	23g	37f	9.6h	13.1g	0.2ef	0.8f	0.58h	0.71g

*The 224 mT/ha treatment applied 207, 78.6, 6.8 and 2.0 ug/g soil of Zn, Cu, Ni and Cd, respectively.

**Means within a column not followed by the same letter are significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 3. Coefficients of determination (r^2) obtained from the simple correlations between DTPA extractable Zn, Cu, Ni and Cd levels (Y) and various soil parameters (X) for limed metal salt treatments equivalent to 56 or 224 mT/ha of Washington, D.C. sewage sludge.

		Soil Parameters+										
Metal	MSE Level	OM	Clay (%)	Fe_o	Fe_d	Total Fe	Total Mn	CEC	CaEC	KEC	'Vr' (%)	Ext Mn
Zinc	56	.229	.245	.124	.348*	.125	.141	.460*	.290	.292	.244	.044
	224	.221	.276	.126	.162	.311	.332*	.570**	.371*	.375*	.330	.078
Copper	56	.036	.226	.041	.050	.049	.004	.118	.209	.123	.182	.022
	224	.008	.365*	.099	.299	.252	.183	.368*	.419*	.308	.391*	.017
Nickel	56	.012	.122	.033	.020	.036	.015	.074	.050	.078	.022	.064
	224	.010	.206	.046	.166	.118	.012	.053	.177	.197	.138	.003
Cadmium	56	.095	.523**	.277	.420*	.484*	.346*	.343*	.429*	.445*	.302	.157
	224	.085	.270	.201	.619**	.562**	.131	.338*	.460*	.422*	.409*	.279

+Abbreviations: OM=organic matter content; Fe_o=oxalate extractable Fe; Fe_d=dithionite-citrate extractable Fe; CEC=cation exchange capacity determined by 1 N NH_4OAc; CaEC=calcium exchange capacity; KEC=potassium exchange capacity; 'Vr'=vermiculite determined on a whole soil basis, and Ext Mn=double acid extractable manganese.

* and ** denote significance at the 5 and 1% levels, respectively.

Table 4. Corn yields after a 30 day growth period from the 224 dry mT/ha (100 T/A) sludge equivalent metal salt treatments after a 13 month "equilibration". All values are averages of three replications.

Soil-Horizon		Yield (g/pot) Limed	Unlimed
Torhunta	A1	11.4abc*	15.0ab
	B2g	5.8c	3.5c
Evesboro	Ap	18.1a	11.8b
	B2	8.7bc	3.5c
Downer	Ap	16.5a	17.8a
	B2	14.2ab	14.6ab
Collington	Ap	18.0a	15.6ab
	B2t	12.0abc	12.8b
Manor	Ap	12.7ab	15.2ab
	B2	11.4abc	12.2b
Myersville	Ap	13.0ab	16.2ab
	B2t	14.2ab	12.9b

*Means within a column not followed by the same letter are significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 5. Tissue metal concentrations from the 224 dry mT/ha (100 T/A) sludge equivalent metal salt treatments after a 13 month "equilibration". All values are averages of three replications.

Soil-Horizon		Plant-Zinc		Plant-Copper		Plant-Nickel		Plant Cadmium	
		Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
		ug/g							
Torhunta	A1	81e*	168d	8.5bcd	7.0b	1.1b	1.2bc	10.1bc	13.8bc
	B2g	166bc	368a	10.7ab	18.1a	2.5a	3.6ab	19.7a	25.3a
Evesboro	Ap	152bcd	365a	7.0cd	9.8ab	1.1b	4.0a	8.7bc	16.0b
	B2	350a	287abc	13.7a	11.0ab	2.7a	3.3ab	22.9a	11.1bcd
Downer	Ap	145bcde	218cd	8.7bcd	7.6b	1.1b	1.6cd	11.6b	9.9bcd
	B2	123bcde	246cd	7.1cd	8.7b	1.4b	2.0cd	10.5b	15.9b
Collington	Ap	175b	339ab	9.0bc	10.0ab	1.4b	3.5ab	10.8b	11.0bcd
	B2t	131bcde	382a	7.0cd	8.0b	0.7b	2.6abc	10.4b	21.7a
Manor	Ap	144bcde	218cd	7.2cd	7.7b	0.9b	0.9d	5.2bc	8.4cd
	B2	113bcde	225cd	6.4cd	7.7b	1.0b	0.8d	5.2bc	10.1bcd
Myersville	Ap	86de	189cd	5.6ce	6.2b	0.8b	0.6d	3.8c	6.1d
	B2t	100cde	167d	5.2d	5.9b	1.5b	1.0d	7.2bc	8.8cd

*Means within a column not followed by the same letter are significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 6. Cd/Zn ratios for the DTPA extractable Cd and Zn levels from the soils sampled 13 months after initiation of the experiment and the corresponding plant Cd/Zn ratios for the 224 dry mT/ha (100 T/A) metal salt equivalent treatment.

		Cd/Zn			
		DTPA		Plant	
Soil-Horizon		Limed	Unlimed	Limed	Unlimed
Torhunta	A1	.066a*	.019a	.125a	.083a
	B2g	.036b	.014d	.120a	.068ab
Evesboro	Ap	.021e	.014d	.057def	.044cd
	B2	.017f	.014d	.064cde	.038cd
Downer	Ap	.027d	.018b	.079bc	.045cd
	B2	.026d	.016c	.085b	.064b
Collington	Ap	.021e	.015cd	.061cdef	.032d
	B2t	.025d	.014d	.079bc	.062b
Manor	Ap	.025d	.020a	.036g	.038cd
	B2	.016f	.014d	.046efg	.045cd
Myersville	Ap	.032c	.018b	.044fg	.032d
	B25	.025d	.019a	.070bcd	.052bc

* Means within a column not followed by the same letter are significantly different at the 5% level according to Duncan's Multiple Range Test.

Figure 1. Plots of DTPA extractable Zn over time from the Downer Ap soil receiving the 224 dry mT/ha sewage sludge addition and the limed and unlimed metal salt equivalent treatments (levels shown on the plots are metal equivalents in dry mT/ha). The horizontal lines intercepting the y-axis indicate the total applied metal levels at each successive, increasing treatment level. These maxima are 12.9, 51.7, and 207 µgZn/g soil at the 14, 56, and 224 (or sludged) metal salt equivalent treatments, respectively.

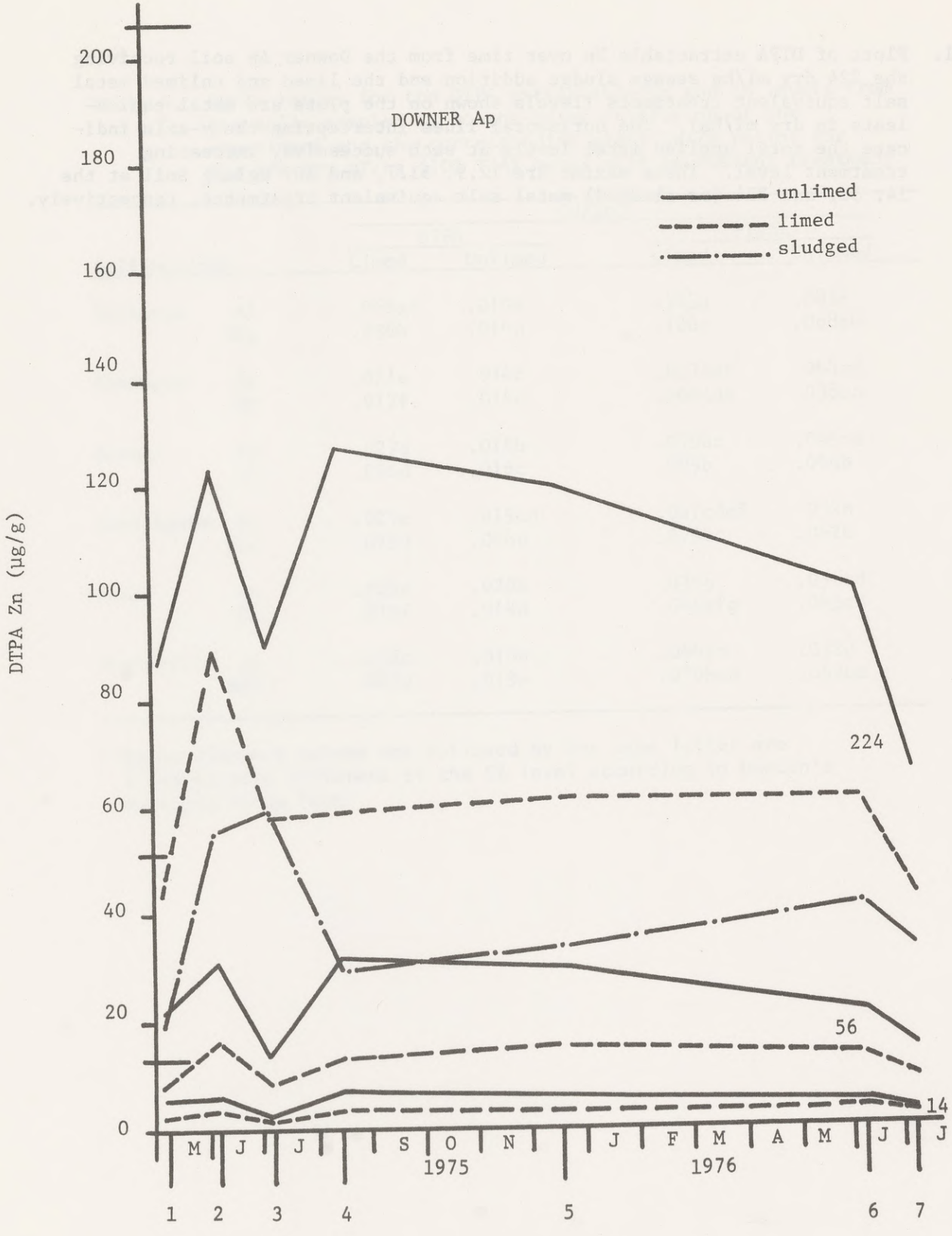
DOWNER Ap
unlimed
limed
sludged
DTPA Zn (µg/g)
200
180
160
140
120
100
80
60
40
20
0
224
56
14
M J J S O N J F M A M J J
1975
1976
1 2 3 4 5 6 7
SAMPLING TIMES

Figure 1

Figure 2. Plots of DTPA extractable Cd over time from the Downer Ap soil receiving the 224 dry mT/ha sewage sludge addition and the limed and unlimed metal salt equivalent treatments (levels shown on the plots are metal equivalents in dry mT/ha). The horizontal lines intercepting the y-axis indicate the total applied metal levels at each successive, increasing treatment level. These maxima are 0.5, 1.0 and 2.0 µgCd/g soil at the 14, 56, and 224 (or sludged) metal salt equivalent treatments, respectively.

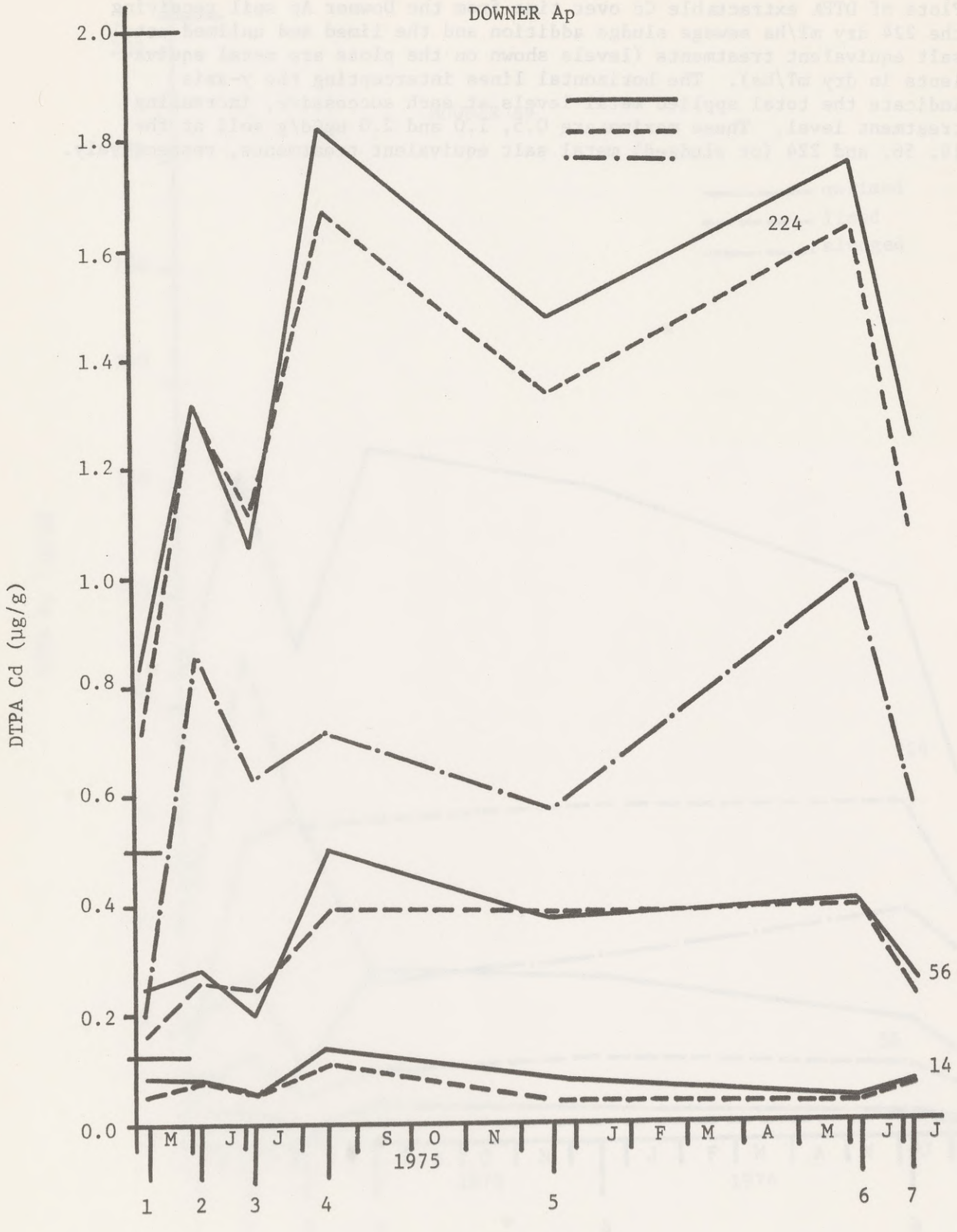
DOWNER Ap
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
DTPA Cd (µg/g)
224
56
14
M
J
J
S
O
N
J
F
M
A
M
J
J
1975
1
2
3
4
5
6
7
SAMPLING TIMES

Figure 2

The Importance of Indigenous Soil Mn in Soil Heavy Metal Studies

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Purpose and Objectives

The input of heavy metals to agricultural soils from sewage sludges has created much concern. This concern stems from the fact that the applied metals become, for the most part, an integral part of the soil-plant system with little or no output from the system besides that removed by crops or soil surface erosion. There is also growing concern that the entire range of elemental inputs from wastes, e.g. sewage sludges, be given attention. However, it is also important to take into account the levels of indigenous soil metals prior to waste application and to consider the effects of applying additional metals or high quantities of foreign metals on those metals already present and the resultant effects on crop growth.

This report focuses on the effect of different indigenous soil Mn levels from a range of Maryland soils and the effects of applied Cd, Cu, Ni, and Zn on Mn uptake by greenhouse grown corn (Zea mays L.).

Materials and Methods

The six soil types utilized, soil characterization data, metal salt equivalent and sludge treatments and the experimental design are presented in a companion paper (Extractability and Uptake by Corn of High Concentrations of Cd, Cu, Ni, and Zn Applied to Different Soil Materials at Two pH Regimes).

Extractable soil Mn for these soils was estimated by the double acid (0.05 N HCl plus 0.025 N H_2SO_4) procedure of the University of Maryland Soil Testing Laboratory and total soil Mn was determined using a

modified HF digestion procedure of Jackson (1958). Plant tissue Mn concentrations were determined for the second crop of 30-day-old corn grown in the greenhouse. The second crop of corn was grown 13 months after initiation of the treatments. Tissue analysis was performed by the dry ash procedure of Isaac and Johnson (1975).

Manganese was not added in the metal salt equivalent treatments. However, the 224 dry mT/ha sewage sludge amendment added a total of 70.2 ug Mn/g soil (based on a total Mn content in the sewage sludge of 702 ug/g).

Results

The soils used in the study displayed a wide range of both double acid extractable and total soil Mn levels (Table 1). The Myersville and Manor soils contained the highest levels of both total and extractable Mn compared to all other soils. This is a reflection of the mafic igneous-metamorphic parent rock of the Myersville soil and micaceous schist-quartzite parent rock of the Manor soil. Such materials are known to produce generally higher metal contents than other rock types (Baker and Chesnin, 1975). Double acid extractable Mn levels were, except for the Torhunta and Manor, higher from the A horizons versus the corresponding B horizons. The percentage of the total soil Mn found to be double acid extractable was usually near or below 10%. However, the Evesboro Ap soil had 25% of the total soil Mn in a double acid extractable form (Table 1).

The tissue Mn levels from the 30-day-old corn plants grown 13 months after initiation of the experiment from all soil-treatment combinations are presented in Table 2. Under unlimed conditions, increasing levels of

metal (Cd, Cu, Ni, and Zn) salts equivalent to various rates of Washington, D.C. digested sewage sludge increased tissue Mn levels independent of soil type. Although no definitive toxicity levels for incipient Mn toxicity to corn, especially 30-day-old corn, are available, tissue levels above 500 ug/g are thought to be indicative of Mn toxicity. Tissue Mn levels above 500 ug/g were noted from the unlimed Collington Ap, Manor Ap and B2 and Myersville Ap and B2t soils (Table 2). This level was reached at the 224 and 896 dry mt/ha metal salt treatments to the unlimed Manor Ap soil and at the 896 dry mt/ha metal salt treatment to all other unlimed soils listed. Therefore, high levels of metal salts (equivalent to or greater than 224 dry mt/ha sewage sludge) may be inducing a Mn toxicity in the corn. The limed soils did not produce tissue Mn levels above 500 ug/g regardless of treatment level. The highest tissue Mn levels, however, were produced from the limed Manor Ap soil at the 896 dry mt/ha metal salt treatment. None of the plants grown on the sewage sludge amended soils (Table 2) contained above 500 ug Mn/g tissue. In the sludge amended soils, the highest average Mn tissue levels were found in the corn grown on the Manor Ap and B2 soils, 354 and 384 ug Mn/g, respectively. It should be noted that the metal salt equivalent treat- ments did not apply additional Mn to the soils while the 224 dry mt/ha sewage sludge treatment added 70.2 ug Mn/g soil.

All three treatment conditions, limed, unlimed, and sludged are comparable at the 224 dry mt/ha level over all soils (Table 3). At this level, the limed Myersville B2t soil produced significantly higher tissue Mn levels compared to all other limed soils. The unlimed Manor Ap and the

sludged Manor Ap and B2 soils produced significantly higher tissue Mn levels than all other unlimed and sludged soils, respectively (Table 3). The Myersville Ap soil, which contained the highest total soil Mn level among all soils, produced very low levels of tissue Mn under both limed and unlimed conditions at the 224 dry mt/ha treatment (Table 3). With the exception of the unlimed Myersville Ap soil, increasing tissue Mn levels were associated with increasing double acid extractable or total soil Mn levels for the unlimed or sludged soils. The percent double acid extractable of total Mn present in the soils did not seem to be a good indicator of tissue Mn levels under limed, unlimed or sludged conditions. The role of the applied metals, Cd, Cu, Ni, or Zn, taken separately or considered in the light of possible interactions on the tissue Mn levels reported cannot be overlooked. Generally, as applied Zn or Cd increased, uptake of these metals increased (Korcak, 1977), however, Ni and Cu did not exhibit this trend. Although not examined, it has been shown by several researchers that metals (Cu, Cd, and Zn) may accumulate in and possibly cause injury to the root system. The effects of increased uptake of the applied metals and/or possible interference with the normal functioning of the root system on tissue Mn levels remains an unknown parameter. However, it does seem apparent that indigenous soil Mn levels need to be taken into consideration prior to the application of high loads of metals from wastes. This point is highlighted by the conclusion reached in the companion paper whereby, prior to investigating soil and tissue Mn, it was found that the Manor soil was the "best choice" for receiving wastes containing heavy metals. However, this study indicates

that although soils like the Manor may be good for transforming added heavy metals to a plant unavailable form, a new problem may be encountered.

Conclusions

Examination of indigenous soil Mn levels and the effects of high metal additions from metal salts or sewage sludge on tissue Mn levels in corn revealed that high soil Mn levels prior to waste application may limit the use of certain soils as repositories of sludges. This study also indicates that additional research is needed on the interactions between Mn and other metals, notably Zn and Cd, when applied at high rates to soils. Attention should be given not only to indigenous soil Mn levels but also other metals which may result in enhanced metal uptake under waste utilization systems.

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Table 1. Double acid (0.05N HCl plus 0.025 N H_2SO_4) extractable and total Mn levels plus the percent extractable of total Mn in the field sampled soils employed in the study. All values are averages of three determinations.

Soil - Horizon		Double Acid Extractable	Total	Extractable as % of Total
		---------- ug/g ---------		
Torhunta	A1	0.5	76	0.6
	B2g	0.5	87	0.6
Evesboro	Ap	6.5	26	25.0
	B2	2.5	25	10.0
Downer	Ap	26	236	11.0
	B2t	17	259	6.6
Collington	Ap	18	300	6.0
	B2t	1.5	228	0.6
Manor	Ap	70	656	10.7
	B2	69	1130	6.1
Myersville	Ap	60	1573	3.8
	B2t	40	1275	3.1

Table 2. Tissue Mn concentrations from the 30-day-old corn plants grown 13 months after initiation of the experiment. All values are averages of three replications followed by the standard deviation.

		Treatment (dry mt/ha)*										
		Limed					Unlimed					Sludged
Soil - Horizon		0	14	56	224	896	0	14	56	224	896	224
Torhunta	A1	53±10	19±13	17±10	20±6	NA	39±15	43±4	48±6	68±6	NA	110±16
	B2g	63±12	36±3	41±6	88±4	NA	23±3	59±18	55±2	124±20	NA	87±11
Evesboro	Ap	24±18	24±8	28±4	56±8	NA	36±6	67±14	60±6	132±13	NA	42±10
	B2	35±10	38±5	46±10	102±25	NA	24±12	44±2	45±8	85±19	NA	43±19
Downer	AP	32±3	35±7	38±12	75±29	NA	143±20	178±17	215±18	277±53	NA	126±53
	B2t	47±4	39±15	36±11	51±11	NA	93±20	95±2	104±12	171±35	NA	114±23
Collington	Ap	21±2	NA	30±7	77±10	130±35	88±10	NA	98±7	199±17	588±113	100±18
	B2t	36±8	NA	31±8	36±19	27±10	74±4	NA	91±9	111±3	133±31	121±29
Manor	AP	46±6	NA	44±3	75±14	312±251	130±47	NA	199±116	719±69	3095±998	354±7
	B2	68±21	NA	87±12	106±8	194±38	153±21	NA	220±11	408±28	938±426	384±21
Myersville	Ap	49±12	NA	44±1	65±4	97±29	51±4	NA	49±6	60±14	569±33	178±26
	B2t	165±47	NA	141±9	169±6	138±44	140±18	NA	202±12	309±34	521±34	200±17

* Treatments for the limed and unlimed conditions are in metal salt contents of Cd, Cu, Ni and Zn equivalent to the dry mt/ha sludge value listed.

Table 3. Tissue Mn concentrations from the 30-day-old corn plants grown 13 months after initiation of the experiment from the limed and unlimed 224 dry mt/ha (100 T/A) metal salt equivalent and 224 dry mt/ha sewage sludge treatments. All values are averages of three replications.

Soil - Horizon		Treatment		
		Limed	Unlimed	Sludged
		---------- ug/g ----------		
Torhunta	A1	20 g*	68 gh	110 c
	B2g	88 bcd	124 efg	87 c
Evesboro	Ap	56 ef	132 ef	42 d
	B2	102 bc	85 fgh	43 d
Downer	Ap	75 de	277 c	126 c
	B2t	51 ef	171 de	114 c
Collington	Ap	77 cde	199 d	100 c
	B2t	36 fg	111 fgh	121 c
Manor	Ap	75 de	719 a	354 a
	B2	106 b	408 b	384 a
Myersville	Ap	65 de	60 h	178 b
	B2t	169 a	309 c	200 b

*Means within a column not followed by the same letter are significantly different at the 5% level according to Duncan's multiple Range Test.

Respiration Rate of Soil Amended with Salt Sprayed Soybean Residue

G. McClung and D.C. Wolf

Purpose and Objectives

The natural-draft cooling tower at the Chalk Point power plant began operation during 1975. This cooling tower utilizes brackish water and hence the potential exists for deposition of significant quantities of salt on the surrounding plants and soils. An extensive monitoring project is under way to determine salt deposition rates on plants and soils. Research efforts are also in progress to determine salt effects on plant and soil metabolism. This study was designed to investigate the effects of the addition of salt treated soybean residue on the soil respiration rate. The experiments measured the rate of decomposition of ground soybean plant material which had been treated with various salt levels during the growing season.

Procedures

The soybean plant material used for this study was a composite sample provided by Dr. C. L. Mulchi and J. A. Armbruster and represented samples collected during the course of an experiment to determine the effect of various rates of salt drift on soybean yield and nutrient balance. The results have been previously reported (Preoperational Report of Cooling Tower Effects on Crops and Soils. 1976. University of Maryland, College Park, Md.).

The soybean plants had been sprayed with NaCl in applications of 0.0, 5.6, 11.2, 16.8, and 22.4 kg/ha wk for eight weeks during the growing season. The applications consisted of daily sprayings for five days per week. The entire leaf canopies of the soybean plants were removed from approximately ten plants per plot after the eighth week. The Na, Cl, and P content and yield of the soybean plants are presented in Table 1. There were four replications of each

salt level. Sub-samples of the plant material were mixed to obtain a representative composite sample for the respiration study. One gram of each of the combined plant samples was added to 200 g of a Chester silt loam soil, mixed and adjusted to 60% moisture holding capacity. All treatments were replicated three times with blanks included.

Microbial respiration was measured by use of a CO_2 evolution apparatus. This system allowed water saturated, CO_2 free air to continuously pass over the soil into a KOH solution where respired CO_2 was trapped. Potassium hydroxide samples were collected over a 14 week period and titrated to determine the rate of soil respiration and plant material decomposition.

Results

The respiration rates of the soybean residue amended soils are presented in Table 2. The results indicate that salt spray levels up to and including 22.4 kg/ha week had no effect on the decomposition rate of the plant material. Approximately 417 mg C as CO_2 was evolved from all soils amended with the plant residue during the 98 day period of the study. The soybean residue containing 0.27% Na and 0.98% Cl was decomposed at the same rate as residue containing 0.11% Na and 0.05% Cl (Table 1) when added to the soil at a rate of 0.5% by weight. The soil not amended with plant residue exhibited a respiration rate of 192.0 $\pm$ 4.3 mg C as CO_2 during the 98 day experiment. Decomposition rate of the plant residue was found to be approximately 50% in all cases during the 14 week experiment.

Previous research has shown that addition of NaCl to the soil at a rate equal to or greater than 2,500 ppm resulted in a 22% reduction in soil microbial respiration and sharply reduced nitrification in the soil during a 14 week period. Results from these studies suggest that the salt level in the soil influences microbial respiration at high levels but does not affect the ability of the soil microbial population to decompose plant material containing elevated levels of NaCl.

Summary

It was concluded that NaCl levels up to and including 22.4 kg/ha wk on soybean plants had no effect on the decomposition rate of the plant residue when added to the soil at a rate of 0.5%. It was concluded that salt drift would result in severe soybean yield reduction long before the decomposition rate of the plant residue in the soil would be effected.

Table 1. Sodium, chloride, and phosphorus content of soybean plants harvested after eight weeks of salt spray treatment. Yields for soybeans subject to eight weeks of salt spray are also presented.[a/]

Salt Treatment (kg/ha week)	Na	Cl	P	Yield (kg/ha)
	----------%----------			
0.0	0.11	0.05	0.33	2,650
5.6	0.14	0.40	0.32	2,728
11.2	0.21	0.75	0.32	2,386
16.8	0.27	0.90	0.35	2,072
22.4	0.27	0.98	0.38	1,430
LSD(0.05)	0.05	0.19	0.02	322
CV%	17.3	20.0	4.5	22.2

[a/] Data from Mulchi, C.L. and J.A. Armbruster, 1976.

Table 2. Evolution of CO_2 from soil amended with soybean residue at the rate of 0.5%. The soybean residue was from plants treated with five levels of NaCl spray for eight weeks.

Time (Days)	Rate of NaCl applied to soybeans (kg/ha week) 0.0	5.6	11.2	16.8	22.4
	mg C as CO_2				
9	252.8±1.6[a/]	249.8±1.5	244.2±0.8	245.6±1.6	246.6±0.7
16	289.1±1.1	287.7±1.6	282.1±1.3	281.4±2.0	283.9±1.7
44	354.8±6.9	362.1±2.8	355.4±1.1	349.8±2.7	352.3±2.9
98	416.6±4.3	422.2±4.2	419.9±6.3	411.1±2.2	414.9±4.8

[a/] All values are means ± one standard deviation.

Influence of Montmorillonite, Micronutrients, pH and Nitrogen Source on the Growth of *Penicillium frequentans*

R. W. McCormick and D. C. Wolf

Purpose and Objectives

Montmorillonite has been shown to stimulate the rate of growth and total biomass production of microorganisms. Maintenance of a more favorable pH, improved micronutrient nutrition, concentration of enzymes on clay surface, adsorption of metabolic waste products, and stimulation of metabolic pathways are theories suggested to explain the stimulation of microbial growth by clays. The objective of this study was to determine the effect of micronutrients, pH, and montmorillonite saturated with different cations on the growth of *Penicillium frequentans*.

Procedure

Montmorillonite #25 from Upton, Wyoming was used as the clay source. The montmorillonite was treated with hydrogen peroxide to remove organic matter. The < 2 um fraction was collected by centrifugation, washed 3 times with NaCl or $CaCl_2$, and then washed 3 times with distilled water until chloride free. Ten milliliters of the clay suspension (500 mg dry wt) was added to dialysis tubing which had been treated to remove contaminates. For a control 10 ml of water was added to the dialysis tubing.

Eighty milliliters of an inorganic salts medium containing NH_4Cl or $NaNO_3$ as the nitrogen source, K_2HPO_4, $MgSO_4$, and KCl along with the dialysis tubing was autoclaved in 250 ml culture flasks. Spores of *P. frequentans* were grown for 2 days on the same medium, homogenized in a blender and 10 ml added as an inoculum. Ten milliliters of a glucose solution was added

as a carbon source. A trace element solution containing Fe, Zn, Mo, Co, B, and Cu was added to the medium where indicated. Samples were placed on an orbital shaker and connected to a CO_2 trap containing KOH. In pH studies a 0.2 M phosphate buffer at pH 6.0 or 7.2 was used. All treatments were in triplicate and harvested after four and six days growth. Fungal growth was recovered by filtration and dry weight determined after freeze drying. Nitrogen content of the fungal biomass was determined by the semi-micro Kjeldahl procedure. Evolved CO_2 was determined titrimetrically.

Results

Table 1 presents the data on the growth of P. frequentans as influenced by montmorillonite treatment, trace element addition and nitrogen source. With NO_3-N, after four days growth, the montmorillonite treatment increased biomass and CO_2 production with and without trace elements present. The montmorillonite treatment without trace elements produced as much biomass as the control with trace elements. The combination of trace elements and montmorillonite resulted in the greatest biomass and CO_2 production. After six days growth the montmorillonite treatment still resulted in greater biomass without trace elements, but not with trace elements. The greater biomass of the control over the montmorillonite treatment with trace elements may be due to autolysis of the fungi occurring in the montmorillonite treatment, which results in a decrease in biomass with the montmorillonite treatment. This reasoning is based on the greater CO_2 evolved with the montmorillonite treatment with trace elements compared to its control.

With NH_4-N as the nitrogen source, after four days growth, the montmorillonite treatment increased biomass and CO_2 production over the controls while there was no difference between the montmorillonite treatments

with and without trace elements. After six days the montmorillonite treatment without trace elements had slightly greater biomass than with trace elements.

The comparison of Ca versus Na saturated montmorillonite on growth of P. frequentans is presented in Table 2. The only difference in biomass production occurred with NH_4-N after four days growth where the Na montmorillonite treatment resulted in greater biomass than the Ca montmorillonite or the control. The Ca montmorillonite treatment increased the nitrogen content of the fungi over that of Na montmorillonite or the control.

Table 3 presents data on the comparison of Ca and Na montmorillonite, pH, and nitrogen source on the growth of P. frequentans. For both nitrogen sources, growth was generally greater at pH 6.0 than 7.2.

As in Table 2 there are no large differences between treatments due to the large standard deviation. After six days growth with NH_4-N at pH 6.0 there was no difference between Ca and Na montmorillonite but they did produce greater biomass than the control. With NO_3-N after six days growth there appears to be no difference between treatments.

Summary

Montmorillonite contained in dialysis tubing may increase the early rate of growth of P. frequentans when NO_3-N is used as a nitrogen source, however, the control will reach the same amount of growth in six days. With NH_4-N as the nitrogen source the montmorillonite addition results in increased biomass after six days growth. Preliminary results indicate that buffering the pH or the supplying trace elements do not fully explain the mechanism by which clay stimulates growth.

Table 1. Effect of Na saturated montmorillonite and trace elements on growth of P. frequentans with NH_4-N and NO_3-N as nitrogen sources.

Treatment	No Trace Elements		Trace Elements Added	
	dry wt	C evolved as CO_2	dry wt	C evolved as CO_2
	mg/100 ml			
		NO_3-N 4 day		
Montmorillonite	705 ± 44[1/]	279 ± 22	788 ± 15	331 ± 9
Control	337 ± 37	134 ± 10	681 ± 16	232 ± 16
		NO_3-N 6 day		
Montmorillonite	777 ± 22	433 ± 32	858 ± 6	499 ± 2
Control	421 ± 64	190 ± 21	916 ± 33	354 ± 12
		NH_4-N 4 day		
Montmorillonite	689 ± 13	219 ± 7	692 ± 36	222 ± 17
Control	521 ± 32	162 ± 5	615 ± 25	182 ± 6
		NH_4-N 6 day		
Montmorillonite	965 ± 20	389 ± 14	917 ± 5	372 ± 15
Control	663 ± 58	222 ± 19	765 ± 11	296 ± 13

1/ Mean of three replications followed by ± one standard deviation.

Table 2. Comparison of Ca and Na saturated montmorillonite on growth and metabolic activity of P. frequentans with NH_4-N and NO_3-N as nitrogen sources.

Treatment	Nitrogen Source: NH_4-N Dry Weight	NH_4-N C evolved as CO_2	NH_4-N N Content	NO_3-N Dry Weight	NO_3-N C evolved as CO_2	NO_3-N N Content
	mg/100 ml		%	mg/100 ml		%
			4 day			
Na mont.	750 ± 11 [1/]	178 ± 1	5.9 ± 0.2	449 ± 33	161 ± 18	6.5 ± 0.1
Control	686 ± 26	167 ± 1	6.1 ± 0.1	411 ± 14	148 ± 8	6.3 ± 0.1
Ca mont.	713 ± 5	176 ± 1	6.5 ± 0.1	412 ± 24	156 ± 6	6.4 ± 0.1
			6 day			
Na mont.	1194 ± 87	331 ± 20	4.8 ± 0.2	821 ± 81	339 ± 36	6.0 ± 0.1
Control	1093 ± 117	316 ± 30	4.7 ± 0.1	817 ± 47	331 ± 33	5.9 ± 0.3
Ca mont.	1180 ± 22	335 ± 3	5.2 ± 0.1	834 ± 93	358 ± 44	6.1 ± 0.1

[1/] Mean of three replications followed by ± one standard deviation.

Table 3. Comparison of Ca and Na saturated montmorillonite on growth and metabolic activity of P. frequentans buffered at pH 6.0 and 7.2 with NO_3-N and NH_4-N as nitrogen sources.

Treatment	pH 6.0 dry wt	pH 6.0 C evolved as CO_2	pH 7.2 dry wt	pH 7.2 C evolved as CO_2
	mg/100 ml			
		NO_3-N 4 day		
Na mont.	485 ± 33[1/]	202 ± 20	499 ± 29	232 ± 13
Control	539 ± 25	221 ± 7	478 ± 43	222 ± 26
Ca mont.	562 ± 40	242 ± 18	462 ± 24	231 ± 14
		NO_3-N 6 day		
Na mont.	735 ± 44	425 ± 20	516 ± 43	397 ± 5
Control	730 ± 34	372 ± 72	523 ± 10	392 ± 7
Ca mont.	746 ± 10	426 ± 30	509 ± 31	402 ± 6
		NH_4-N 4 day		
Na mont.	900 ± 10	266 ± 6	721 ± 18	194 ± 7
Control	853 ± 73	244 ± 19	707 ± 50	194 ± 11
Ca mont.	935 ± 26	266 ± 6	746 ± 29	212 ± 12
		NH_4-N 6 day		
Na mont.	931 ± 10	382 ± 13	868 ± 37	360 ± 16
Control	897 ± 9	400 ± 6	877 ± 23	358 ± 14
Ca mont.	933 ± 5	392 ± 5	814 ± 27	382 ± 12

[1/] Mean of three replications followed by ± one standard deviation.

Irrigation with Maryland Tobacco, 1976

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Department of Agronomy

Purpose and Objectives

Presently between 15 and 20% of the Maryland tobacco crop can be irrigated if needed. Supplemental water is not necessary every year, but in some seasons the crop value can be doubled. Thus, the objective of this experiment is to gather long term data on the benefit of irrigation to the production of Maryland tobacco and to determine if there is a differential variety response to irrigation.

Procedure

The experiment was a split plot design. Main plots were irrigation and sub plots were varieties — Md. 10, Md. 609, Md. 872, Md. 201, and breeding lines M-19 and 314. There were four replications for a total of 48 plots.

The test was located at the University of Maryland Tobacco Experimental Farm. The soil was a Monmouth fine sandy loam. The fertilizer application was 90 lbs. N, 120 lbs. P_2O_5 and 180 lbs. K_2O equivalent per acre.

Water was applied to the plots requiring irrigation when the plants started to show moisture stress in the heat of the day. A Skinner overhead pipe system was used for irrigation.

Fifteen plants were harvested and cured from each plot. The cured plants were stripped into farmer grades, weighed, U.S.D.A. grades assigned and priced according to grade. Yield per acre and value was then calculated. A representative sample of the cured leaves from the whole plant was taken for chemical analysis and a leaf from the mid portion of the stalk of each plant was saved for leaf burn and filling capacity tests.

Plants were transplanted into the field on June 3. One irrigation of about $1\frac{1}{4}$ inches of water was applied on July 29. The plants were topped on August 6 and harvested on August 18.

Results

The results from the tobacco irrigation study are in Table 1. Irrigation was not needed until the latter part of the growing season. As expected the later maturing varieties Md. 872 and Md. 201 had the greatest response to this application of water. Md. 10, our earliest maturing variety, had a slight decrease in yield with irrigation. The other lines in the test had small increases in yield in response to irrigation. The average for the test was an overall increase of $64 per acre from irrigation.

Summary

The 1976 growing season was dry in latter July and one irrigation of $1\frac{1}{2}$" of water was applied on July 29. This was followed by .7 inch of rainfall. The later maturing varieties Md. 201 and Md. 872 responded the greatest to irrigation with increases of $129 and $142 per acre respectively. The earlier maturing Md. 10 had a slight decrease in per acre value with irrigation. The other lines in the test had small increases in acre value with irrigation.

Table 1. Summary of tobacco irrigation test — 1976.

Variety	Yield/Acre lbs.	Cents/lb.	$/Acre	Response to irrigation - $
		Irrigated		
Maryland 609	1852	98.1	1816	+ 48
Maryland 872	1969	98.4	1937	+ 142
Maryland 201	2009	96.7	1942	+ 129
Maryland 10	1776	96.2	1709	- 33
BL M-19	1836	96.8	1777	+ 15
BL 314	1971	96.8	1908	+ 81
Average	1902	97.1	1848	+ 64
		Not Irrigated		
Maryland 609	1801	98.1	1768	
Maryland 872	1853	96.9	1795	
Maryland 201	1862	97.4	1813	
Maryland 10	1791	97.3	1742	
BL M-19	1820	96.8	1762	
BL 314	1915	95.4	1827	
Average	1840	97.0	1784	

Low Plant Population Studies with Maryland Tobacco

C. G. McKee
Department of Agronomy

Purpose and Objectives

Tobacco production requires about 230 man-hours of labor per acre. This is because the individual plants are handled many times: pulling from seedbed, transplanting, topping, harvesting, and stripping. Earlier studies with population rates ranging from 6223 to 9680 plants per acre showed that total yield per acre, although often greater at the higher plant population levels, was not proportional to the number of plants per acre. Thus, as plant populations were increased, yield per plant was reduced. The purpose of this test was to study lower than normal plant populations with the idea of determining maximum or optimum levels of production per plant. This would help growers get maximum production per hour of labor.

Procedure

The field test was located on a Monmouth fine sandy loam soil. Four plant population levels, 6223, 4978, 4149, and 3556 plants per acre at 3 nitrogen rates, 50, 70, and 90 pounds per acre were studied. The test was a split-plot design with nitrogen rates as main plots and plant populations as the split plots. Four replications were made and Maryland 872 variety was used. The test was irrigated as needed to maintain optimum growing conditions. At harvest, the sticks of green tobacco were weighed to determine green weight per plant. After curing, the plots were stripped, weighed, graded and priced. Yield per acre and dollar value, yield per plant and % yield of cured leaf to green weight were computed.

Although not an integral part of the test, 18 non-competitive plants were grown to try to determine the maximum potential production of a plant. These plants were spaced 7 feet on centers.

Results and Discussion

The results for the 1976 season of the low plant population studies with Maryland tobacco are in Table 1. The 1976 growing season was dry in early August and one irrigation of $1\frac{1}{2}$" of water was applied. The tobacco in the test was rather severely infected with tobacco etch virus and appeared somewhat stunted. Green weight of plants was less than in 1974 or 1975; however, the % yield of cured leaf to green weight was over $9\frac{1}{2}$%, the highest for the 3 years.

In spite of the smaller tobacco caused by the virus infection, the trends of the 2 previous years work continued. The lower plant population levels decreased yield per acre and dollar return, but increased green weight per plant and cured leaf per plant. There was little difference in the % yield of cured leaf to green weight over the plant population rates tested. However, none of the plant population rates tested approached the level of green weight per plant, cured leaf per plant, and % cured leaf to green weight obtained from the non-competitive plants.

Response to nitrogen was the greatest between the 70 and 90 pound per acre rates with an average yield increase of 121 pounds of cured leaf. There was only an average increase in yield of 37 pounds comparing the 70 and 50 pound per acre nitrogen rates.

In the 1976 season, using the average of all nitrogen rates, if 6223 plants were planted in 42 inch rows with a spacing in the row of:

24 inches, 1 acre is covered for a gross return of $1857

30 inches, 1-1/4 acres are covered for a gross return of $2153

36 inches, 1-1/2 acres are covered for a gross return of $2375

42 inches, 1-3/4 acres are covered for a gross return of $2618.

Summary

The low plant population study with Maryland tobacco was initiated in 1974 and continued in 1975 and 1976. Although the growing seasons were quite different, the major trends were the same. The lower plant populations decrease yield per acre, but increase yield per plant. Green weight per plant also increases with decreasing plant populations, but average green weights per plant were less in 1975 and 1976 than in 1974. It appears from this study thus far that Maryland tobacco farmers would get more return from their labor planting less than 5000 plants per acre than planting over this level.

Table 1. Summary of low plant population study with Maryland tobacco - 1975.

Nitrogen rate (lbs/A)	Plant population per acre	Yield/Acre lbs.	Cents/lb.	$/Acre	Green Wt./Plant lbs.	Cured Leaf Wt./Plant lbs.	% Cured Leaf of Green Wt./Plant
50	6223	1846	98.2	1813	3.17	.30	9.36
	4978	1604	98.3	1578	3.36	.32	9.63
	4149	1538	98.4	1512	3.83	.37	9.72
	3556	1497	99.0	1481	4.34	.42	9.69
Average		1621	98.5	1596	3.67	.35	9.60
70	6223	1863	96.7	1798	3.16	.30	9.49
	4978	1770	100.5	1769	3.65	.36	9.72
	4149	1572	99.7	1576	3.97	.38	9.54
	3556	1426	99.1	1416	4.33	.40	9.28
Average		1658	98.9	1638	3.78	.36	9.51
90	6223	2008	97.7	1961	3.37	.32	9.60
	4978	1842	98.8	1819	3.80	.37	9.73
	4149	1681	99.3	1671	4.11	.41	9.88
	3556	1586	100.1	1587	4.66	.45	9.60
Average		1779	98.8	1759	3.98	.39	9.70
Average	6223	1905	97.5	1857	3.23	.31	9.48
over all	4978	1739	99.1	1722	3.60	.35	9.69
nitrogen	4149	1597	99.1	1583	3.97	.39	9.71
rates	3556	1503	99.4	1496	4.44	.42	9.52
Non-Competitives					6.39	.70	10.95

The Response of Alfalfa to Irrigation Fertility and Cutting Management

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Purpose and Objectives

Alfalfa is the leading quality hay crop in the Northeast. Acreage of this crop is increasing, partly due to the availability of improved varieties with higher yield potential than the standard cultivars. Although varietal improvement has made significant progress and fertilization practices have changed, other alfalfa management practices have not changed in the past fifteen years.

The overall purpose of this study is to provide new data on alfalfa management by comparing a new cultivar (WL 311) with an old one (Williamsburg). This is being accomplished by looking at the yield and stand persistence under: (1) irrigation and non-irrigation; (2) fertilization at the recommended rate, one-half that rate, and double that rate; and (3) four cutting schedules. Forage quality was also evaluated through chemical analysis.

Procedure

The experimental planting was made in fall, 1973, on a Chester loam soil. Soil test results for 1976 showed a pH of 7.0 with MgO in the high range. The medium fertility plots recorded P_2O_5 in the high range and K_2O as medium. The low fertility treatments had a medium level of P_2O_5 and a low level of K_2O. The high fertility plots showed very high for both P_2O_5 and K_2O. Before the alfalfa broke dormancy in spring, 1976, 0-37.5-75 was applied to the low fertility plots, 0-75-150 to the medium fertility plots and 0-150-300 to the high fertility.

During the 1976 growing season the plots were harvested according to

the following management schedules: One fourth of the plots were harvested at early bud followed by 30-day intervals for the rest of the growing season. One fourth of the plots were harvested at full bud followed by 30-day intervals. One fourth were harvested at full bud followed by 40-day intervals, and the final one fourth of the plots were harvested at half bloom followed by 40-day intervals. There were five harvests in the plots cut every 30 days and four harvests for those cut every 40 days.

At the beginning of the 1976 growing season, tensiometers were placed in some of the irrigated plots. These tensiometers were placed at depths of 4 and 12 inches. During the growing season irrigation was applied when the tensiometers indicated that the plants were approaching a period of moisture stress.

Results

No significant differences between the irrigated and non-irrigated plots were noted in 1976. An analysis of the data show that differences in dry matter yield between cultivars, cutting treatments, fertility levels, cutting treatments X fertility levels, fertility levels X cultivars, and cutting treatments X cultivars were statistically significant at the 1% level. Means for the significant treatment effects are shown in tables 1, 2, and 3. Chemical analyses for forage quality have not been completed.

Summary

Yields of weed free alfalfa for the 1976 growing season for the new cultivar WL311 were significantly higher than for the older variety, Williamsburg. Cutting treatments showed significant differences in yield with the half-bloom-40 day interval yielding most followed by the full bud-40 day interval, then the full bud-30 day interval, and last the early bud-30 day interval. In the three fertility levels, the high rate produced significantly more forage than the medium and low rates.

Table 1. Interactions of cutting treatments X cultivars expressed in metric tons per hectare of weed-free alfalfa. 1976

Cutting Treatments	Cultivars		
	WL 311 T/ha	Williamsburg T/ha	Average
Half-bloom followed by 40-day interval	11.19 a[1/]	10.09 b	10.66 W
Early bud followed by 30-day interval	7.57 d	5.58 f	6.58 Z
Full bud followed by 30-day interval	8.42 c	6.50 e	7.46 Y
Full bud followed by 40-day interval	9.60 b	8.50 c	9.05 X
Average	9.22 A	7.64 B	

1/ Any two means not followed by the same letter are significantly different at the 1% level. Duncan's Multiple Range Test.

Table 2. Interactions of cutting treatments X fertility levels expressed in metric tons per hectare of weed-free alfalfa. 1976.

Cutting Treatments	Fertility Levels[1/] Low T/ha	Medium T/ha	High T/ha	Av.
Half-bloom followed by 40-day interval	9.92 ab	10.76 a	11.31 a	10.66 W
Early bud followed by 30-day interval	6.06 e	5.74 e	7.94 cd	6.58 Z
Full bud followed by 30-day interval	6.28 de	7.19 cde	8.92 bc	7.46 Y
Full bud followed by 40-day interval	8.39 bc	8.77 bc	9.99 ab	9.05 X
Average	7.66 B[2/]	8.11 B	9.54 A	

1/ Low = $\frac{1}{2}$ soil test recommendation, Medium = soil test recommendation, High = double soil test recommendation

2/ Any two means not followed by the same letter are significantly different at the 1% level. Duncan's Multiple Range Test.

Table 3. Interactions of fertility levels X cultivars expressed in metric tons per hectare of weed-free alfalfa. 1976.

Fertility levels[1/]	Cultivars		
	WL 311 T/ha	Williamsburg T/ha	Average
Low	8.46 b[2/]	6.87 c	7.66 X
Medium	8.84 b	7.39 c	8.12 X
High	10.32 a	8.71 b	9.54 Y
Average	9.22 A	7.64 B	

1/ Low = $\frac{1}{2}$ soil test recommendation; Medium = soil test recommendation; High = double soil test recommendation

2/ Any two means not followed by the same letter are significantly different at the 1% level. Duncan's Multiple Range Test.

Influence of Nitrogen Sources on the Response of Maryland Tobacco to Chloride Fertilization

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Purpose and Objectives

Field studies with Maryland tobacco have shown that additions of chloride to the soil or applied by foliar spray can alter the agronomic, chemical and physical properties of cured tobacco. Research with other types of tobacco have revealed that nitrate sources of nitrogen reduced the impact of the chloride on tobacco, especially with regard to burning quality. A sizable acreage of tobacco is grown in an area surrounding the cooling towers at Chalk Point which are currently being investigated for their potential for salt damage to crops. Information contained in this report is a summary of the second year's results from a study involving the combination of soil chloride and nitrogen sources on Maryland tobacco.

Procedures

During the summer of 1976, a study was conducted at the Tobacco Experimental Farm near Upper Marlboro, Md. in which tobacco was planted in plots fertilized with five rates of chloride and three sources of nitrogen in a split-plot design with three applications. The whole plot treatments were the application of 0, 22, 44, 66 and 88 kg/ha of chloride from $CaCl_2$. The $CaCl_2$ was applied uniformly over the soil with spray equipment prior to planting. The subplot treatments were three sources of nitrogen - ammonium sulfate, ammonium nitrate and calcium nitrate. The rate of nitrogen application for all plots was 99 kg/ha - ie. 66 kg/ha of N at preplant and 33 kg/ha of N as sidedressing. An individual plot consisted of two rows 1 m apart and 7.6 m long with plants spaced 0.6 m

apart in the rows. Border rows were used to separate the whole plots but not the subplots. All plots were fertilized with other nutrients at rates recommended by the Soil Testing Laboratory.

Variety Md. 609 was utilized for the study. The plants were planted, cultured, harvested, cured, and stripped consistent with recommended procedures for Maryland air-cured tobacco. At harvest, 10 uniform plants were cut from each plot row, speared onto sticks then hung in the barns for air curing. During stripping, information was collected on yields (lbs/A), average price ($/100 lbs), value ($/A), and quality (0-100). From composite samples obtained from the various grades for each plot on a proportionate weight basis, data on total alkaloids, total nitrogen, and the P, K, Ca, Mg, Na and Cl contents in the cured tissue were determined in the laboratory. Burn (sec) and filling capacity (cm^3/g) tests were conducted on 25-leaf samples pulled from the "bright" grade from each plot.

Results

The results in Tables 1 and 2 summarize the agronomic, chemical and physical characteristics of the cured tobacco. The yield of tobacco was not significantly affected by the chloride or nitrogen source treatments; however, the average price, value, quality, alkaloid and chloride contents were significantly changed by treatments. The lowest prices, values and alkaloid levels were observed in the plots treated with ammonium sulfate. Increasing the level of soil chloride significantly reduced the quality of the cured tobacco and increased the chloride level in the leaves from 0.050 to 0.816 percent. Although nonsignificant, the price and value of the tobacco tended to be lower with increased soil chloride levels.

Due to the large variation in the burn data, the reductions in burn with increased soil chloride were not statistically significant at the 95 percent level of probability. However, the trend for reduced burn with increased chloride is consistent with earlier observations. Apparently leaching rains earlier in the growing season removed a substantial portion of the chloride from the root zone, thus reducing the level of chloride uptake by the plants. The level of chloride taken up in the present study was approximately one-half that observed in the 1975 study. The calcium nitrate treatment tended to reduce the impact of soil chloride on leaf burn.

Regarding the effects of both the soil chloride and nitrogen source treatments on the nutrient contents in composite samples of cured tobacco, the calcium nitrate significantly reduced the potassium and magnesium contents but increased the calcium contents in the samples. The metabolic index (ratio of P + K + Ca + Mg/Na + Cl) was significantly reduced by the increase in soil chloride. The phosphorus content appeared not to be affected by treatments.

Summary

Tobacco plants were exposed to increasing levels of chloride as $CaCl_2$ applied to the soil and to three sources of nitrogen $(NH_4)_2SO_4$, NH_4NO_3 and $Ca(NO_3)_2$) to determine if the source of nitrogen affected the plants response to chloride. Information on agronomic, chemical and physical properties of cured tobacco were obtained. Lower prices, value and alkaloid levels were observed with $(NH_4)_2SO_4$ treatments. The quality of the tobacco was substantially reduced with increased soil chloride and prices, value and burn tended to be lower at the highest chloride level. $Ca(NO_3)_2$ significantly reduced the potassium and magnesium con-

tents and increased calcium contents in the leaves. The chloride content in the leaves was significantly increased and metabolic index reduced with increased soil chloride levels.

Acknowledgement

Financial support for the research was provided by the Maryland Department of Natural Resources - Power Plant Siting Program and administered through the Water Resources Research Center. The authors wish to thank Dr. Richard Nietubica, Project Engineer for the Chalk Point Cooling Tower Project, and Dr. R. L. Green, Coordinator of the Water Resources Research Center, for their assistance with the project.

Table 1. Agronomic, chemical and physical properties of cured tobacco grown with soil chloride additions combined with three nitrogen sources. 1976.

Treatment		Agronomic				Chemical		Physical	
Soil Chloride (C) kg/ha	N Source[1/] (N)	Yield lb/A	Price $/100 lb	Value $/A	Quality 0-100	Nitrogen %	Alkaloid %	Burn Sec	Filling Capacity cm^3/g
0	1	1625	92.94	1509	67.45	2.62	2.067	8.51	7.3
	2	1843	94.69	1748	65.64	2.23	2.293	10.98	6.5
	3	1707	96.15	1641	71.93	2.56	2.030	12.32	7.2
22	1	1746	92.68	1620	56.55	2.60	2.011	11.98	7.3
	2	1877	93.18	1755	65.06	2.54	2.177	13.84	6.6
	3	1657	93.10	1543	60.00	2.30	2.209	12.74	7.1
44	1	1739	91.25	1587	53.13	2.42	1.770	10.30	7.1
	2	1754	91.74	1609	49.29	2.63	2.081	8.00	6.7
	3	1802	92.50	1666	54.80	2.63	1.878	10.85	7.5
66	1	1733	87.92	1531	49.62	2.55	1.889	11.47	7.1
	2	1755	93.98	1647	64.51	2.71	2.076	10.51	7.2
	3	1699	94.77	1613	57.81	2.11	2.152	7.19	6.7
88	1	1657	91.11	1511	49.76	2.04	1.984	4.11	6.4
	2	1792	91.52	1640	48.35	2.51	2.123	5.80	6.5
	3	1720	92.28	1587	50.97	2.40	2.016	8.15	6.6
		Whole-plot (C) and Sub-plot (N) Averages							
0	-	1725	94.59	1633	68.34	2.47	2.130	10.60	7.0
22	-	1760	92.99	1639	60.54	2.48	2.132	12.85	7.0
44	-	1765	91.83	1620	52.44	2.47	1.909	9.72	7.1
66	-	1729	92.22	1597	57.31	2.46	2.038	9.72	7.0
88	-	1723	91.64	1580	49.69	2.32	2.041	6.02	6.5
-	1	1700	91.17	1551	55.30	2.45	1.944	9.27	7.0
-	2	1804	93.02	1679	58.58	2.53	2.150	9.83	6.7
-	3	1717	93.76	1610	59.12	2.35	2.057	10.25	7.0
Grand Mean		1740	92.65	1614	57.67	2.44	2.050	9.78	6.9
LSD (0.05) C		90	4.62	149	10.29	0.30	0.423	4.46	0.6
N		95	1.42*[2/]	97*	4.82	0.27	0.163*	2.78	0.4
N/C		212	3.18	217	10.80	0.60	0.364	6.22	0.8
CV (%) C		4.7	4.6	8.5	16.4	11.3	18.9	41.9	7.7
N		7.1	2.0	7.9	11.0	14.5	10.4	37.3	7.2

[1/] 1 = Ammonium sulfate, 2 = Ammonium nitrate, 3 = Calcium nitrate

[2/] Significant at 95% level of probability

Table 2. Summary of the effects of nitrogen sources and soil chloride additions on the nutrient contents of composite samples of cured tobacco. 1976.

Treatments		Nutrient Contents						Metabolic Index
Soil Chloride (C) kg/ha	N Source (N) [1/]	P %	K %	Ca %	Mg %	Na %	Cl %	
0	1	0.18	4.06	1.68	1.25	0.097	0.057	47.30
	2	0.18	4.00	1.75	1.07	0.093	0.044	51.27
	3	0.18	3.93	1.84	0.99	0.086	0.050	51.42
22	1	0.18	3.93	1.73	1.11	0.089	0.081	41.33
	2	0.19	3.76	1.85	1.10	0.091	0.113	35.22
	3	0.18	3.66	1.87	1.05	0.089	0.088	38.75
44	1	0.17	3.93	1.79	1.19	0.084	0.285	17.95
	2	0.18	3.63	1.81	1.10	0.103	0.241	19.71
	3	0.16	3.53	2.00	1.06	0.098	0.356	15.70
66	1	0.18	3.97	1.81	1.29	0.099	0.644	10.31
	2	0.17	3.87	1.95	1.21	0.097	0.563	12.30
	3	0.16	3.57	1.91	1.11	0.094	0.394	13.92
88	1	0.17	3.83	1.79	1.17	0.078	0.827	8.27
	2	0.17	3.57	1.91	1.29	0.090	0.879	7.26
	3	0.17	3.50	1.94	1.13	0.096	0.742	8.64
		Whole-plot (C) and Sub-plot (N) Averages						
0	-	0.18	4.00	1.76	1.10	0.092	0.050	50.00
22	-	0.18	3.79	1.82	1.08	0.089	0.093	38.43
44	-	0.17	3.70	1.87	1.12	0.095	0.294	17.78
66	-	0.17	3.80	1.89	1.20	0.096	0.533	12.18
88	-	0.17	3.63	1.88	1.20	0.088	0.816	8.06
-	1	0.18	3.93	1.76	1.20	0.089	0.378	25.03
-	2	0.18	3.77	1.86	1.15	0.095	0.367	25.15
-	3	0.17	3.64	1.91	1.07	0.093	0.326	25.69
Grand Mean		0.17	3.78	1.84	1.14	0.092	0.357	25.29
LSD (0.05)	C	0.01	0.31	0.27	0.29	0.01	0.186* [2/]	5.95*
	N	0.01	0.16*	0.09*	0.10*	0.01	0.098	2.94
	N/C	0.02	0.36	0.20	0.22	0.01*	0.222	6.57
CV (%)	C	7.5	7.5	13.6	23.2	11.5	48.1	21.6
	N	7.6	5.5	6.2	11.2	7.1	36.5	15.3

[1/] 1 = Ammonium sulfate, 2 = Ammonium nitrate, 3 = Calcium nitrate

[2/] Significant at 95% level of probability.

Effects of Simulated Salt Drift on Maryland Tobacco Using Brackish Water from Cooling Towers at Chalk Point

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Purpose and Objectives

In studies[1/] investigating the responses of Maryland tobacco to additions of chloride either to the soil as $CaCl_2$ or from foliar sprays as NaCl, Maryland tobacco was observed to rapidly accumulate chloride from both sources. Also, evidence that small amounts of chloride may be beneficial was observed;[2/] however, excessive amounts of chloride may adversely affect the quality of tobacco. The cooling towers at Chalk Point, which began operations in May of 1975, are projected to release sizable quantities of salts into the atmosphere. However, with adequate atmospheric dispersion, only small quantities are projected to be deposited on the crops growing near the towers. It was of interest to examine the response of tobacco to applications of spray mist using brackish water from the operating towers in amounts within the range of the quantities projected for the area near the towers. The information contained in this report is a summary of the second year's results from a study involving the response of tobacco to simulated salt drift using cooling tower water.

Procedures

A study was conducted at the Tobacco Experimental Farm near Upper Marlboro, Md. during the summer of 1976 on a Monmouth fine sandy loam soil. The soil was fertilized according to soil test recommendations and utilized

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1/ C. L. Mulchi and W. W. Newcomb. 1975. Crops and Soils Research. Md. Agri. Exp. Sta. 8: 194-199; 8: 200-205.

2/ C. L. Mulchi, W. W. Newcomb and J. A. Armbruster. Crops and Soils Research, Md. Agri. Exp. Sta. 9: 185-197.

variety Md. 609. The tobacco was planted, cultured, harvested, cured and stripped consistant with established practices for Maryland air-cured tobacco.

A randomized complete block design with four replications was employed. A plot consisted of four rows spaced one meter apart and 7.6 meters in length. The plants were spaced 0.6 meters apart in the rows. The two center rows received the treatments and the two outside rows served as border rows to reduce drift contamination from adjacent plots. Four treatments with brackish water were employed: control, 17.1, 34.2 and 51.3 liters/ha/day. The treatments were applied with a motorized sprayer equipped with three sets of four nozzles each spaced 0.5 meters apart. The four nozzles (Conejet TXISS, Agrotec Inc., Salisbury, Md.) were spaced to apply the simulated drift uniformly over the two center rows in the plots. The sprayer was equipped with a combination valve which allowed the application of 1X, 2X or 3X with X being the amount of spray from a single set of four nozzles. The pressure relief valve was set at 4.22 kg/cm^2 (60 psi) and each nozzle was checked and found to deliver 1.3 ml/sec. From previous work, the mean droplet size for the spray mist was observed to be about 100 microns in size. A ground speed of about 1.5 m/sec was maintained for the daily treatments. With the combination valve and the three sets of nozzles, all treatments could be accomplished in a single pass. It should be noted that the machine was driven through the control plots even though no spray mist was being applied. For all treatments, the nozzles were adjusted to about 0.5 meters above the plant canopy.

In mid-June, after the plants had become established following transplanting, a supply of water was obtained from the operating cooling tower at Chalk Point. The sediments in the brackish water were allowed to settle out for several days then sediment-free water was siphoned from the top of

the container directly into the tank on the sprayer. The electrical conductivity (E. C.) of the water was found to be 31.2 mmhos/cm or about 20,000 ppm total salts. The treatments were applied daily five days per week. A second batch of water was collected after four weeks of spraying and its salinity was almost identical to the first batch. The second batch was used through the eighth week when treatments were terminated.

Vegetative samples were collected after three weeks of treatments when the tobacco plants were about 0.5 meters in height and when the plants were flowering. These samples were rinsed with distilled water, oven dried at 70 C, ground, then analyzed for P, K, Ca, Mg, Na and Cl contents.

In late August, a few days following the last spray application, the plots were harvested by cutting ten uniform plants from each of the two center rows. The plants were speared onto sticks and placed in barns for curing. After curing, data was collected on plot yields (lbs/A), average price ($/100 lbs), value ($/A), and quality index (1-100). Composite samples were obtained from the cured tobacco and analyzed for P, K, Ca, Na, Cl, total alkaloids and total nitrogen contents. A 25 leaf sample was randomly selected from the "bright" grade (center stalk position) and subjected to burn and filling capacity tests.

Results

The results for the chemical analysis of the green leaf samples for nutrient contents are summarized in Table 1. The results for the young tobacco show significant increases in sodium and chloride contents and a reduction in the metabolic index with increased rate of salt spray. At flowering, there were trends for increased potassium, calcium and magnesium contents with increased spray application suggesting the plants may be benefiting from the nutrients contained in the cooling tower water. Also, the sodium and chloride contents were significantly higher with increased

spray rates. The relative magnitude of the increases in sodium and chloride contents were similar for both growth stages suggesting that the rate of uptake for these ions equaled the rate of growth of the plants. The levels of chloride attained in the green leaves at flowering were within the normal range of chloride found in Maryland tobacco thus should not be viewed with alarm. These low levels of chloride have been shown to stimulate growth without damaging the burn of the cured tobacco.

The results in Table 2 summarize the agronomic, chemical and physical properties of the cured tobacco. Yields were significantly increased by the salt spray treatments but quality was lowered at the highest treatment rate. Burn was not affected by the treatments but filling capacity tended to be lower at the highest rate of spray. These results would suggest that cooling tower drift up to 34.2 l/ha/day may be more beneficial than harmful since yields were increased without affecting price or quality of the tobacco. Drift above 34.2 l/ha/day may be harmful to tobacco quality.

The results in Table 3 summarize the chemical analysis of the composite samples of cured tobacco. The trends observed in the green leaf samples at flowering appear to have carried over into the composite samples of cured tobacco.

Summary

Tobacco grown at the Tobacco Experimental Farm and exposed to treatments utilizing brackish water from operating cooling towers at Chalk Point to simulate salt drift from the towers on crops showed beneficial affects of the treatments up to 34.2 l/ha/day. Yield of tobacco increased significantly and value tended to be higher with low rates of simulated drift. Tobacco quality, average price and filling capacity tended to be lower at the 51.3 l/ha/day spray rate using cooling tower water with 20,000 ppm salinity. Burn, alkaloid and nitrogen contents were not affected by treatments but

sodium and chloride levels were significantly increased. The levels of chloride attained in the green and cured tobacco from the highest treatment was within the normal range for tobacco grown throughout the tobacco producing region in Maryland.

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Table 1. Effects of simulated salt drift using water from the Chalk Point cooling towers on the nutrient contents in green leaves of tobacco. 1976.

Treatment Spray Volume 1/ l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	Metabolic Index 2/
Young Tobacco							
0	0.13	4.50	4.59	1.37	0.094	0.246	31.16
17.1	0.15	4.28	3.93	1.17	0.103	0.308	23.21
34.2	0.14	4.20	4.10	1.16	0.111	0.266	25.50
51.3	0.14	4.05	3.89	1.27	0.115	0.332	21.09
Average	0.14	4.25	4.13	1.24	0.105	0.287	25.23
LSD(0.05)	NS	NS	NS	NS	0.013	0.055	2.81
CV(%)	9.1	5.9	12.2	8.7	7.9	12.0	7.0
Tobacco at Flowering							
0	0.26	3.08	2.86	0.93	0.116	0.087	35.09
17.1	0.27	3.55	2.82	0.87	0.151	0.159	24.38
34.2	0.28	3.38	3.15	1.08	0.149	0.221	22.36
51.3	0.26	3.10	3.80	1.08	0.169	0.281	16.55
Average	0.26	3.28	2.90	0.99	0.146	0.187	24.59
LSD (0.05)	NS	0.32	NS	NS	0.027	0.093	6.94
CV(%)	6.7	6.1	10.8	26.6	11.4	31.2	17.7

1/ Applied as 100 micron droplets containing 20,000 ppm salinity five days per week.

2/ Metabolic Index calculated by P+K+Ca+Mg/Na+Cl.

Table 2. Effects of simulated salt drift using water from the Chalk Point cooling towers on the agronomic, chemical and physical properties of Maryland tobacco. 1976.

Treatments		Agronomic				Chemical		Physical	
Spray Volume 1/	Total Salts Applied	Yield	Price	Value	Quality	Alkaloid	Nitrogen	Burn	Filling Capacity
l/ha/day	kg/ha	lbs/A	$/100 lbs	$/A	0-100	%	%	Sec	cm^3/g
0	0	1700	93.00	1581	70.04	2.409	2.80	7.68	14.40
17.1	14.5	1959	94.53	1854	70.44	2.283	2.74	7.98	17.4
34.2	29.0	1860	93.74	1748	70.38	2.518	2.92	7.50	14.3
51.3	43.5	1993	92.55	1847	63.77	2.676	3.13	7.58	10.9
Average		1878	93.45	1751	68.66	2.471	2.90	7.68	14.3
LSD(0.05)		196	NS	NS	4.69	NS	NS	NS	NS
CV(%)		6.5	1.9	7.9	4.3	19.1	8.6	8.9	24.9

1/ Treatments were applied as 100 micron droplets containing 20,000 ppm salinity five days per week for about eight weeks.

Table 3. Effects of simulated salt drift using water from the Chalk Point cooling towers on the nutrient contents in composite samples of cured tobacco. 1976.

Treatments		Nutrient Contents						Metabolic Index
Spray Volume 1/ l/ha/day	Total Salts Applied kg/ha	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.21	3.34	1.73	1.18	0.041	0.072	54.46
17.1	14.5	0.20	4.10	1.67	1.18	0.084	0.144	31.98
34.2	29.0	0.20	4.00	1.77	1.26	0.110	0.220	22.70
51.3	43.5	0.20	3.85	1.81	1.35	0.160	0.229	20.28
Average		0.20	3.82	1.74	1.24	0.098	0.166	32.35
LSD(0.05)		NS	NS	NS	NS	0.059	0.074	16.55
CV(%)		12.1	23.1	8.9	14.8	37.5	27.7	32.0

1/ Treatments were applied as 100 micron droplets containing 20,000 ppm salinity five days per week for about eight weeks.

Effects of Simulated Salt Drift on Corn and Soybeans Using Brackish Water from the Cooling Towers at Chalk Point

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Purpose and Objectives

In conjunction with an on-going research and monitoring program examining the effects of salt drift from the cooling towers at Chalk Point on crops and soils, it was of interest to expose corn and soybeans to various levels of salt drift using brackish water from the operating towers. Of particular interest were the effects of salt drift on yields and nutrient contents in the leaves of the plants. From previous studies involving the foliar application of NaCl to corn and soybeans[1/], corn plants were observed as being moderately tolerant to salt spray early in the growth cycle but became more sensitive with plant maturity whereas soybeans appeared to increase in tolerance to salt spray with plant maturity. However, corn yields appeared more subject to being reduced than soybean yields from salt spray applications. This report summarizes the second year's results from a study simulating salt drift using cooling tower water on corn and soybeans.

Procedures

The procedures described in the preceding report for investigating the effects of simulated salt drift on Maryland tobacco were identical to those used in the current studies. The plot sizes, statistical designs and treatments were the same as those previously described. The reader is referred to that report for details on procedures used in the current studies.

1/ C. L. Mulchi and J. A. Armbruster. 1975. Crops and Soils Research. Md. Agri. Exp. Station. 8: 206-218; 9: 194-201.

The varieties of corn and soybeans planted were Pioneer 3369A and York, respectively. Both studies were fertilized according to soil test recommendations and the experiments were planted in early June. Spray treatments were initiated as soon as plant stands were assured.

Vegetative samples were collected from the individual plots for both crops three and six weeks after the spray treatments were initiated. The samples were rinsed with distilled water, oven dried at 70C, ground, then analyzed for P, K, Ca, Mg, Na and Cl.

The spray treatments were terminated after eight weeks and the plants were allowed to complete their growth cycles. Spraying the beans beyond eight weeks would risk substantial mechanical damage to the plant canopy. The corn had completed pollination and was rapidly approaching maturity when the treatments were terminated. The plots were harvested in the fall and yield estimates were determined from 6 meter lengths from the two center rows.

Results

The results in Tables 1 and 2 summarize the analyses of foliage samples for both growth stages for corn and soybeans, respectively. In most instances, the sodium and chloride contents of both species were increased significantly by the spray treatments with both plant species showing somewhat similar responsiveness regarding sodium and chloride uptake. The metabolic index for both species was significantly reduced by spray treatments in both species with the relative magnitude of the decrease being somewhat larger for the soybeans. The effects of treatments on other plant nutrients were nonsignificant which suggest that there were no beneficial effects from the treatments as observed with tobacco in the previous report.

The results in Table 3 summarize the yield data from both crop species.

There were nonsignificant changes in yields with increased spray treatments. The corn yields tended to show increases with spray applications which differ from previous observations. Normally corn is more sensitive than soybeans to salt spray regarding yields. These results do suggest that corn and soybeans may be grown with tower drift containing 20,000 ppm salinity at rates up to 51.3 l/ha/day without substantial damage. No visual damage was observed during the study.

Summary

Corn and soybean plants were exposed to salt spray treatments utilizing brackish water from the cooling towers at Chalk Point. Both species showed significant increases in sodium and chloride contents with increased rates of spray with no appreciable affects on other plant nutrients. No visual damage was observed during the study. The yields of both crop species were not significantly changed by treatments suggesting that both crop species may be able to grow within an environment near a cooling tower having brackish water and withstand drift rates as high as 51.3 l/ha/day with water containing 20,000 ppm salinity.

Acknowledgement

Financial support for the research was provided by the Maryland Department of Natural Resources - Power Plant Siting Program and administered through the Water Resources Research Center. The authors wish to thank Dr. Richard Nietubicz, Project Engineer for the Chalk Point Cooling Tower Project, and Dr. R. L. Green, Coordinator of the Water Resources Research Center, for their assistance with the project.

Table 1. Effects of simulated salt drift using water from the Chalk Point cooling towers on the nutrient content of corn at two growth stages. 1976.

Treatment Spray Volume 1/	Nutrient Contents						Metabolic Index 2/
	P	K	Ca	Mg	Na	Cl	
l/ha/day	%	%	%	%	%	%	
			Young Corn Plants				
0	0.37	2.36	0.31	0.18	0.114	0.187	13.6
17.1	0.36	3.18	0.29	0.16	0.115	0.191	13.0
34.2	0.36	3.13	0.27	0.14	0.101	0.218	12.2
51.3	0.33	2.90	0.29	0.14	0.120	0.240	10.2
Mean	0.35	3.11	0.28	0.15	0.112	0.209	12.3
LSD (0.05)	NS	NS	NS	NS	0.011	0.022	1.7
CV(%)	5.8	7.1	5.6	11.4	6.3	6.6	8.4
			Corn at Tasseling				
0	0.295	2.40	0.50	0.21	0.102	0.174	12.4
17.1	0.290	2.35	0.54	0.23	0.123	0.186	11.1
34.2	0.242	1.73	0.45	0.24	0.142	0.206	7.4
51.3	0.268	2.03	0.50	0.19	0.171	0.234	7.3
Mean	0.274	2.13	0.50	0.22	0.134	0.200	9.6
LSD(0.05)	NS	NS	NS	NS	0.026	NS	2.8
CV(%)	19.8	22.7	13.2	23.8	12.3	14.3	18.4

1/ Applied five times a week as 100 micron droplets containing 20,000 ppm salinity.

2/ Metabolic Index caluclated by P+K+Ca+Mg/Na+Cl.

Table 2. Effects of simulated salt drift using water from the Chalk Point cooling towers on the nutrient content of soybeans at two growth stages. 1976.

Treatment Spray Volume[1/]	P	K	Ca	Mg	Na	Cl	Metabolic Index[2/]
l/ha/day	%	%	%	%	%	%	
			Young Soybean Plants				
0	0.33	3.05	1.65	1.82	0.116	0.042	43.4
17.1	0.36	3.03	1.81	1.95	0.102	0.073	40.8
34.2	0.31	3.10	1.77	1.71	0.123	0.099	31.1
51.3	0.33	3.08	1.64	1.77	0.127	0.129	26.8
Mean	0.33	3.06	1.72	1.81	0.117	0.086	35.5
LSD(0.05)	NS	NS	NS	NS	0.016	0.020	5.9
CV(%)	12.2	9.9	10.9	20.0	8.9	14.9	10.3
			Soybeans at Flowering				
0	0.29	2.10	1.73	1.54	0.096	0.037	42.7
17.1	0.35	2.05	1.66	1.63	0.104	0.112	26.6
34.2	0.23	1.83	1.38	1.43	0.106	0.167	17.9
51.3	0.32	1.95	1.51	1.51	0.115	0.237	14.9
Mean	0.30	1.98	1.57	1.52	0.105	0.138	25.6
LSD(0.05)	NS	NS	NS	NS	0.010	0.026	8.5
CV(%)	25.0	20.1	20.9	26.8	6.1	11.7	20.8

1/ Treatments were applied five times a week as 100 micron droplets containing 20,000 ppm salinity.

2/ Metabolic index calculated by P+K+Ca+Mg/Na+Cl

Table 3. Effects of simulated salt drift using water from the Chalk Point cooling towers on the yeilds of corn and soybeans. 1976.

Treatments		Corn		Soybeans	
Spray Volume l/ha/day	Total Salt Applied[1/] kg/ha	Bu/A	kg/ha	Bu/A	kg/ha
0	0	102.0	6400	32.0	2150
17.1	14.5	108.7	6820	32.9	2210
34.2	29.0	113.2	7120	31.5	2113
51.3	43.5	113.0	7100	28.9	1940
Mean		109.2	6850	31.4	2110
LSD(0.05)		NS	NS	NS	NS
CV(%)		9.4	9.4	8.3	8.3

[1/] Applied as aerosol spray with droplets approximately 100 microns in size with water averaging 20,000 ppm salinity. Treatments were applied five days per week for eight weeks.

Response of Maryland Tobacco to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers

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Purpose and Objectives

In the environment near a cooling tower using brackish water, there would be a continuous release of salts which may accumulate in the soils and eventually reach an equilibrium where salt deposition and removal by leaching, runoff, plant removal, etc. will be in balance. The prevailing meteorological conditions and soil characteristics will be major factors determining the ultimate equilibrium under a given rate of deposition from the cooling tower. It is of interest to obtain information on the response of tobacco and other crop species growing in such an environment where salts have accumulated in the soil and where deposition of salts from the operating tower continues to occur. The information in this report summarize the initial results from a study where tobacco was grown on soils treated with NaCl and the plants were exposed to simulated salt drift over eight weeks of the growing season.

Procedures

An experiment was conducted during the summer of 1976 at the Tobacco Experimental Farm on a Monmouth fine sandy loam soil where tobacco was grown with NaCl applied to the soil and subjected to simulated salt drift using brackish water from the cooling towers at Chalk Point. The soil was fertilized according to soil test recommendation and the plants were cultured, harvested, cured and stripped consistant with established practices for Maryland air-cured tobacco. Maryland Variety Md 609 was used for the study. A split-plot design with three replications was employed with five rates of soil applied NaCl as whole-plot treatments and three rates of

simulated salt drift with brackish water the subplot treatments. NaCl was applied to the soil with spray equipment at rates of 0, 13.7, 27.5, 55 and 110 kg/ha prior to planting of the tobacco. Following planting, the simulated salt drift treatments were applied using motorized spray equipment (previously described)[1/] five days per week for eight weeks at rates of 0, 34.2 and 68.4 l/ha/day. The brackish water, obtained from the unit No. 3 cooling tower at Chalk Point, contained 20,000 ppm salinity. The drift was applied with nozzles (previously described)[1/] which delivered droplets averaging approximately 100 microns in size. A plot consisted of four rows 7.6 meters in length and one meter apart. The treatments were applied to the two center rows with the outside rows serving as borders to reduce drift contamination from adjacent plots.

The plants were sampled after three and six weeks of spray treatments. The samples were washed, dried at 70°C in a forced air oven, ground, then analyzed for P, K, Ca, Mg, Na and Cl in the Soil Testing Laboratory.

In late August, ten plants from each row were harvested, speared onto sticks and placed in barns for curing. In January, the plants were stripped and data on yields (lbs/A), average price ($/100 lbs.), value ($/A) of quality (0-100) were obtained. Composite samples of the cured tobacco were collected and analyzed for alkaloids, total nitrogen and P, K, Ca, Mg, Na and Cl contents. A twenty-five leaf sample of cured tobacco was collected from the "bright" grade from each plot and burn and filling capacity estimates were made.

[1/] Mulchi, C. L., W. W. Newcomb and J. A. Armbruster. 1976. Crops and Soils Research. Md. Agri. Expt. Sta. 9: 185-193.

Results

The results in Table 1 summarize the nutrient contents of the green leaf samples collected after three weeks of aerial spray treatments. The foliar treatments with brackish water significantly reduced the Ca and Mg contents and significantly increased the Na contents. Potassium levels were also lowered and chloride levels increased but not significantly by the spray treatments. The soil applied NaCl significantly increased the Cl levels and reduced the metabolic index for the plants.

The results in Table 2 summarize the nutrient contents of the green leaves collected six weeks after aerial spray treatments began or when the plants were in flower. The earlier reductions in K, Ca and Mg contents appeared reversed by the spray treatments with significant increases in P, Mg, Na and Cl contents being attributable to the simulated salt drift treatments. The soil salt treatments caused increases in tissue Cl levels only. Both the soil salt and foliar treatments significantly reduced the metabolic index values for the plants. These results would suggest that the aerial spray treatments were more effective than the soil applied salts in affecting the nutrient contents. The increases in P, K, Ca and Mg suggest that some nutrient benefit to the plants may be in order due to the aerial spray with brackish water during the growth of the plants.

The results in Table 3 summarize the effects of treatments on the agronomic, chemical and physical properties of the cured tobacco. The soil applied salt significantly increased the value of the tobacco up to 27.5 kg/ha. However, trends for reduced price, quality and burn at the 55 and 110 kg/ha treatments were noted. Yields increased up to 27.5 kg/ha but not significantly. The 68.4 l/ha/day aerial spray treatment significantly reduced the price and burn of the tobacco and exhibited evidence of lower-

in the quality of the tobacco.

The results in Table 4 summarize the nutrient contents of the composite samples of cured tobacco. In general, the trends were similar to those observed in the green leaf samples collected at flowering.

Summary

Maryland tobacco was grown on plots treated with NaCl at rates of 0, 13.7, 27.5, 55 and 110 kg/ha at preplant then sprayed five days per week for eight weeks with cooling tower water containing 20,000 ppm salinity at rates equal to 0, 34.2 and 68.4 l/ha/day. Green leaf samples taken after three weeks of spraying showed lower Ca and Mg contents and increased Na levels in the tissue attributable to the spray treatments. The soil applied NaCl increased the Cl levels in the tissue and reduced the metabolic index for the tissue. However, after six weeks of spraying, the spray treatments significantly increased the P, Mg, Na and Cl in the leaves and higher K and Ca levels were in evidence. The soil applied NaCl generally increased yield and value of tobacco up to 27.5 kg/ha. The 68.4 l/ha/day foliar treatment reduced the price, quality and burn of the tobacco.

In general, the plants appeared more responsive to the foliar applied salts than the soil applied NaCl. The 68.4 l/ha/day foliar treatment was as damaging as 110 kg/ha of NaCl applied to the soil prior to planting of the tobacco.

Acknowledgement

Financial support for the research was provided by the Maryland Department of Natural Resources - Power Plant Siting Program and administered through the Water Resources Research Center. The authors wish to thank Dr. Richard Nietubicz, Project Engineer for the Chalk Point Cooling Tower

Project, and Dr. R. L. Green, Coordinator of the Water Resources Research Center, for their assistance with the project.

Table 1. Summary of the effects of soil applied NaCl versus aerial spray using cooling tower water on the nutrient contents of leaves of young tobacco. 1976.

Treatments		Nutrient Contents						Metabolic Index
Soil Salt (A) kg/ha	Aerial Spray[1/] (B) l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.15	3.73	4.07	1.12	0.119	0.546	15.29
	34.2	0.16	3.83	3.98	1.02	0.149	0.409	17.07
	68.4	0.15	3.80	3.75	1.15	0.166	0.613	11.39
13.7	0	0.14	3.77	4.15	1.20	0.132	0.878	12.40
	34.2	0.15	3.97	4.00	1.04	0.151	0.670	11.19
	68.4	0.17	3.93	3.78	1.04	0.152	0.679	11.43
27.5	0	0.16	4.27	4.37	1.18	0.130	0.664	13.15
	34.2	0.16	4.20	4.22	1.20	0.155	0.652	12.08
	68.4	0.14	3.23	3.25	0.83	0.159	1.041	7.42
55	0	0.16	3.53	4.40	1.26	0.129	0.951	8.75
	34.2	0.16	3.20	4.25	1.12	0.135	1.327	7.07
	68.4	0.15	3.53	4.62	1.21	0.171	1.036	7.89
110	0	0.16	3.83	4.25	1.11	0.138	1.691	5.21
	34.2	0.18	3.53	3.98	1.19	0.146	1.418	6.19
	68.4	0.17	3.57	3.57	0.92	0.139	1.899	4.11
		Whole-plot (A) and Sub-plot (B) Averages						
0	-	0.15	3.79	3.93	1.09	0.145	0.523	14.58
13.7	-	0.15	3.89	3.98	1.09	0.145	0.743	11.67
27.5	-	0.15	3.90	3.94	1.07	0.148	0.786	10.89
55	-	0.16	3.42	4.42	1.20	0.145	1.104	7.90
110	-	0.17	3.64	3.93	1.07	0.141	1.669	5.17
-	0	0.15	3.83	4.24	1.17	0.129	0.946	10.96
-	34.2	0.16	3.75	4.09	1.11	0.147	0.895	10.72
-	68.4	0.15	3.61	3.79	1.03	0.158	1.054	8.45
Grand Mean		0.16	3.71	4.04	1.11	0.145	0.965	10.04
LSD (0.05)	A	0.03	1.03	0.60	0.18	0.011	0.526*	5.29*
	B	0.01	0.31	0.25*[2/]	0.11*	0.014*	0.245	2.34
	B/A	0.03	0.70	0.56	0.25	0.032	0.549	5.22
CV (%)	A	17.2	25.6	13.7	15.5	6.8	50.1	48.5
	B	12.3	11.0	8.2	13.4	12.9	33.4	30.5

1/ Cooling Tower water was applied as 100 micron droplets containing 20,000 ppm salinity. The 34.2 and 68.4 l/ha/day treatments equal 3.65 and 7.28 kg/ha/wk salt respectively.

2/ Significant at 95% level of probability.

Table 2. Summary of the effects of soil applied NaCl vs. aerial spray using cooling tower water on the nutrient contents of leaves of tobacco at flowering. 1976.

Treatments		Nutrient Contents						Metabolic Index
Soil Salt (A) kg/ha	Aerial Spray[1/] (B) l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.19	2.36	1.78	0.25	0.063	0.251	15.10
	34.2	0.18	2.33	1.80	0.24	0.098	0.276	12.60
	68.4	0.18	2.26	1.79	0.26	0.119	0.413	8.71
13.7	0	0.17	1.97	1.61	0.23	0.067	0.278	11.97
	34.2	0.19	2.36	1.90	0.25	0.102	0.391	9.64
	68.4	0.19	2.73	2.27	0.30	0.152	0.554	8.98
27.5	0	0.18	2.36	1.94	0.25	0.075	0.333	12.86
	34.2	0.18	1.97	1.53	0.21	0.090	0.379	8.30
	68.4	0.17	1.93	1.48	0.21	0.122	0.650	5.22
55	0	0.17	1.93	1.55	0.22	0.075	0.272	11.19
	34.2	0.17	1.83	1.49	0.22	0.082	0.518	6.59
	68.4	0.18	2.03	2.04	0.29	0.139	0.670	5.72
110	0	0.20	2.07	1.69	0.25	0.075	0.660	5.92
	34.2	0.16	2.03	1.94	0.25	0.088	1.027	4.12
	68.4	0.23	2.47	2.39	0.39	0.149	1.165	4.75
		Whole-plot (A) and Sub-plot (B) Averages						
0	-	0.18	2.32	1.79	0.25	0.095	0.313	12.14
13.7	-	0.18	2.36	1.92	0.26	0.107	0.408	10.20
27.5	-	0.17	2.06	1.65	0.22	0.096	0.454	8.80
55	-	0.17	1.93	1.70	0.24	0.099	0.487	7.83
110	-	0.19	2.18	2.03	0.29	0.104	0.951	4.93
-	0	0.18	2.12	1.79	0.22	0.072	0.359	11.41
-	34.2	0.17	2.10	1.74	0.23	0.092	0.518	8.25
-	68.4	0.19	2.29	1.99	0.29	0.136	0.690	6.68
Grand Mean		0.18	2.17	1.82	0.25	0.100	0.522	8.78
LSD (0.05)	A	0.03	0.58	0.43	0.05	0.015	0.346*	3.46*
	B	0.01*[2/]	0.26	0.25	0.03*	0.007*	0.159*	1.71*
	B/A	0.02*	0.58	0.56	0.08	0.017	0.356	3.84
CV(%)	A	14.6	24.6	21.9	19.2	14.1	60.9	36.2
	B	7.9	15.6	18.1	18.3	10.0	40.0	25.7

1/ Cooling tower water was applied as 100 micron droplets containing 20,000 ppm salinity. The 34.2 and 68.4 l/ha/day equals 3.65 and 7.28 kg/ha/day salt, respectively.

2/ Significant at 95% level of probability.

Table 3. Agronomic chemical and physical properties of cured tobacco treated with soil applied NaCl combined with aerial spray of cooling tower water on foliage for eight weeks. 1976.

Treatments		Agronomic				Chemical		Physical	
Soil Salt (A)	Aerial Spray (B) [1/]	Yield	Price	Value	Quality	Nitrogen	Alkaloids	Burn	Filling Capacity
kg/ha	l/ha/day	lbs/A	$/100 lbs	$/A	0-100	%	%	Sec	cm^3/g
0	0	1636	99.12	1621	77.25	2.71	2.473	5.13	7.16
	34.2	1769	99.45	1760	81.15	2.66	2.490	5.54	6.90
	68.4	1762	98.07	1729	75.20	2.59	2.558	3.87	7.27
13.7	0	1879	97.60	1833	73.45	2.57	2.668	3.39	7.70
	34.2	1727	98.67	1703	75.75	2.42	2.373	3.90	7.23
	68.4	1810	77.47	1794	79.68	2.36	2.335	3.46	7.60
27.5	0	1945	100.56	1956	80.68	2.57	2.583	4.26	7.83
	34.2	1811	99.28	1798	76.38	2.48	2.442	3.36	7.56
	68.4	1736	93.65	1732	74.47	2.41	2.536	2.98	7.37
55	0	1821	98.56	1795	72.45	2.36	2.382	4.94	7.50
	34.2	1862	98.17	1828	69.56	2.80	2.514	2.95	7.80
	68.4	1807	97.44	1761	67.94	2.41	2.295	3.08	7.30
110	0	1730	98.87	1710	74.30	2.34	2.356	4.24	7.93
	34.2	1814	97.68	1774	69.53	2.30	2.429	3.74	7.93
	68.4	1830	95.24	1741	59.85	2.34	2.621	1.92	7.30
Whole-plot (A) and Sub-plot (B) Averages									
0	-	1722	98.88	1703	77.86	2.65	2.507	4.84	7.11
13.7	-	1805	98.53	1777	76.29	2.45	2.458	3.59	7.51
27.5	-	1831	99.49	1823	77.17	2.49	2.520	3.53	7.59
55	-	1830	98.06	1795	69.99	2.52	2.396	3.66	7.53
110	-	1791	97.26	1742	67.89	2.33	2.468	3.30	7.72
-	0	1802	98.94	1782	75.62	2.51	2.492	4.39	7.63
-	34.2	1797	98.65	1723	74.48	2.53	2.449	3.90	7.49
-	68.4	1789	97.77	1748	71.43	2.42	2.469	3.07	7.37
Grand Mean		1796	98.45	1768	73.84	2.49	2.470	3.78	7.49
LSD(0.05)	A	79	1.90	35*	10.39	0.32	0.332	1.28	0.82
	B	114	0.90* [2/]	115	3.56	0.21	0.252	0.79*	0.55
	B/A	254	2.01	257	7.95	0.48	0.565	1.77	1.23
CV(%)	A	4.0	1.7	1.8	12.9	11.8	12.4	31.2	10.1
	B	8.3	1.2	8.5	6.3	11.4	13.4	27.5	9.6

1/ Cooling tower water was applied as 100 micron droplets containing 20,000 ppm salinity. The 34.2 and 68.4 l/ha/day equals 3/65 and 7.28 kg/ha/wk salt, respectively.

2/ Significant at 95% level of probability.

Table 4. Summary of the effects of soil applied NaCl vs. aerial spray using cooling tower water on nutrient contents of composite samples of cured tobacco. 1976.

Treatments		Nutrient Contents						Metabolic Index
Soil Salt (A) kg/ha	Aerial Spray[1] (B) l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.23	4.00	1.85	0.84	0.108	0.223	23.35
	34.2	0.22	4.30	2.10	0.93	0.156	0.351	16.03
	68.4	0.20	4.07	2.08	0.94	0.220	0.531	9.91
13.7	0	0.22	3.80	2.11	1.10	0.118	0.422	15.54
	34.2	0.21	4.03	1.96	1.01	0.161	0.371	13.62
	68.4	0.20	4.20	1.98	0.98	0.198	0.761	7.92
27.5	0	0.21	3.87	2.10	1.06	0.088	0.303	19.25
	34.2	0.20	3.73	1.91	0.91	0.179	0.360	12.55
	68.4	0.20	3.87	2.02	0.91	0.235	0.703	7.90
55	0	0.20	3.63	2.18	1.13	0.101	0.342	16.50
	34.2	0.20	3.30	1.75	1.02	0.154	0.543	9.78
	68.4	0.20	3.17	2.08	0.91	0.245	0.819	6.00
110	0	0.22	3.90	2.11	0.95	0.098	0.966	6.06
	34.2	0.20	3.73	2.17	0.87	0.171	1.245	5.26
	68.4	0.21	3.53	2.23	1.00	0.210	1.450	5.10
		Whole-plot (A) and Sub-plot (B) Averages						
0	-	0.22	4.12	2.01	0.91	0.161	0.368	16.43
13.7	-	0.21	4.01	2.02	1.03	0.159	0.518	12.36
27.5	-	0.21	3.82	2.01	0.96	0.167	0.455	13.23
55	-	0.20	3.37	2.00	1.02	0.166	0.567	10.76
110	-	0.21	3.72	2.17	0.94	0.159	1.220	5.47
-	0	0.22	3.84	2.07	1.02	0.102	0.451	16.13
-	34.2	0.21	3.82	1.98	0.95	0.164	0.574	11.45
-	68.4	0.20	3.77	2.08	0.95	0.221	0.853	7.37
Grand Mean		0.21	3.81	2.04	0.97	0.162	0.626	11.65
LSD(0.05)	A	0.02	0.66	0.25	0.13	0.025	0.410*	5.29*
	B	0.01*[2]	0.22	0.16	0.10	0.020*	0.172*	2.53*
	B/A	0.02	0.50	0.35	0.21	0.045	0.386	5.67
CV(%)	A	8.3	16.1	11.1	11.8	14.3	60.3	41.7
	B	5.7	7.8	10.1	12.9	16.5	36.2	28.6

1/ Cooling tower water was applied as 100 micron droplets containing 20,000 ppm salinity. The 34.2 and 68.4 l/ha/day equals 3.65 and 7.28 kg/ha/wk salt, respectively.

2/ Significant at 95% level of probability.

Response of Corn and Soybeans to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers

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Purpose and Objectives

As discussed in the previous report, the response of crops such as corn and soybeans to combined soil applied NaCl and simulated salt drift is of interest due to the possible accumulation of salts in the soil near operating cooling towers using brackish water. The information in this report summarizes the initial results from two studies where corn and soybeans were grown on soil treated with NaCl and the plants were exposed to simulated salt drift over eight weeks of the growing season in 1976.

Procedures

The procedures followed in these studies were nearly identical to those described in the preceeding report for tobacco except the plots were fertilized according to soil test recommendations for corn and soybeans, respectively. Experimental design, treatments, leaf sampling, etc. were as previously described. Pioneer 3369A and York varieties of corn and soybeans, respectively, were used for the studies.

Vegetative samples were collected after three and six weeks (at flowering) of foliar spray with brackish water containing 20,000 ppm salinity. The samples were washed, dried at 70°C, ground and analyzed for P, K, Ca, Mg, Na and Cl contents. The plots were harvested in the fall and grain yields adjusted to 12.5% moisture content.

Results

The results in Tables 1 and 2 summarize the tissue analysis results for corn after three and six weeks, respectively, of simulated salt drift treatments. After three weeks, the only significant effects found were increases in Cl and reductions in metabolic index values (P + K + Ca +

Mg/Na + Cl), both attributable to the soil applied NaCl treatments. After six weeks, there were significant increases in Na and Cl and reductions in metabolic index values attributable to the foliar spray treatments.

The results in Tables 3 and 4 summarize the tissue analysis results for soybeans after three and six weeks, respectively, of simulated salt drift treatments. After three weeks of treatments, the soybeans had significantly higher P, Ca, Mg, Na and Cl levels resulting from the spray treatments. Potassium levels were also somewhat increased. Both treatments increased the Cl levels and decreased the metabolic index values. After six weeks of treatments, only significant increases in Cl and reductions in metabolic index values were noted for both treatments. These results would suggest that young soybean plants were more responsive to the foliar salt treatments than young corn plants.

The results in Table 5 summarize the effects of treatments on yields of both crops. Neither crop was significantly affected by the soil applied NaCl treatments, even up to 110 kg/ha. However, the corn yields were significantly reduced by the simulated salt drift treatments. The soybean yields were lowered slightly but not significantly by the foliar spray treatments. These results confirm earlier observations that corn yields may be adversely affected by salt drift from cooling towers. Although soybeans may show adverse affects to salt drift earlier in their growth cycle, they appear to have the ability to recover late in the growing season.

There were no significant interactions between the soil applied NaCl vs. the foliar salts which suggest that corn and soybean plants do not change their relative sensitivities to salts depending on the levels of

soil vs. foliar applied salts.

Summary

Corn and soybeans were treated with increased rates of soil applied NaCl and simulated salt drift using water from the Chalk Point cooling towers. Young corn plants appeared more sensitive to soil applied NaCl than to the foliar spray. Young soybeans appeared more sensitive to foliar applied salts than to soil applied NaCl. The corn plants appeared to increase and soybeans appeared to decrease in sensitivity to foliar applied salt. Yields of corn were significantly reduced by the foliar applied salts but not by the soil applied NaCl up 110 kg/ha. Soybean yields tended to be lower following foliar salt additions but the results were not significant. No significant interactions between soil vs. foliar salts were observed on either crop species.

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Table 1. Nutrient contents of young corn treated with soil applied NaCl combined with aerial spray of cooling tower water on foliage. 1976.

Treatments		Nutrient Contents						Metabolic Index
Soil Salts (A) kg/ha	Aerial Spray[1/] (B) l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.36	3.60	0.41	0.29	0.103	0.444	8.88
	34.2	0.35	3.20	0.39	0.28	0.105	0.401	8.34
	68.4	0.36	3.47	0.41	0.29	0.125	0.405	8.64
13.7	0	0.39	3.70	0.41	0.32	0.095	0.571	7.33
	34.2	0.41	3.47	0.39	0.34	0.110	0.584	6.70
	68.4	0.37	3.80	0.40	0.32	0.123	0.539	7.42
27.5	0	0.36	3.57	0.42	0.34	0.171	0.653	5.76
	34.2	0.36	3.57	0.42	0.37	0.112	0.676	5.98
	68.4	0.37	3.60	0.39	0.34	0.151	0.699	5.53
55	0	0.35	3.47	0.38	0.25	0.092	0.704	5.68
	34.2	0.35	3.50	0.41	0.27	0.109	0.735	5.57
	68.4	0.34	3.80	0.42	0.32	0.128	0.759	5.51
110	0	0.37	3.27	0.36	0.24	0.096	0.716	5.26
	34.2	0.41	3.53	0.39	0.34	0.106	0.771	5.55
	68.4	0.34	3.33	0.41	0.31	0.127	0.688	5.55
Whole-plot (A) and Sub-plot (B) Averages								
0	-	0.36	3.42	0.40	0.28	0.111	0.416	8.62
13.7	-	0.39	3.66	0.40	0.32	0.109	0.564	7.15
27.5	-	0.36	3.58	0.41	0.35	0.145	0.676	5.76
55	-	0.34	3.59	0.40	0.28	0.109	0.732	5.59
110	-	0.37	3.38	0.38	0.29	0.109	0.725	5.39
-	0	0.36	3.52	0.40	0.29	0.111	0.617	6.58
	34.2	0.38	3.45	0.40	0.32	0.108	0.633	6.38
	68.4	0.36	3.60	0.41	0.31	0.131	0.618	6.53
Grand Mean		0.37	3.52	0.40	0.31	0.117	0.603	6.50
LSD (0.05)	A	0.07	0.37	0.05	0.11	0.05	0.314[2/]*	1.17*
	B	0.02	0.18	0.02	0.05	0.02	0.075	0.65
	B/A	0.05	0.41	0.05	0.10	0.04	0.168	1.45
CV (%)	A	16.6	9.7	10.5	31.6	39.2	20.4	16.6

1/ Applied as 100 micron droplets containing 20,000 ppm salinity
2/ Significant at 95% level of probability.

Table 2. Nutrient contents of corn at tasseling after treatment with soil applied NaCl combined with aerial spray of cooling tower water on foliage. 1976.

Treatments		Nutrient Contents						Metabolic Index
Soil Salts (A) kg/ha	Aerial Spray (B) 1/ l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.28	2.40	0.50	0.09	0.108	0.214	10.35
	34.2	0.23	1.80	0.43	0.06	0.135	0.253	6.71
	68.4	0.28	2.00	0.49	0.09	0.227	0.347	5.34
13.7	0	0.27	2.23	0.46	0.09	0.106	0.320	7.22
	34.2	0.31	2.30	0.52	0.12	0.179	0.322	6.52
	68.4	0.27	2.13	0.48	0.11	0.187	0.379	5.20
27.5	0	0.29	2.23	0.51	0.09	0.116	0.314	7.37
	34.2	0.29	2.40	0.47	0.09	0.154	0.372	6.34
	68.4	0.27	2.17	0.49	0.09	0.177	0.407	5.34
55	0	0.31	2.33	0.50	0.09	0.119	0.398	6.28
	34.2	0.28	2.27	0.50	0.10	0.162	0.462	5.09
	68.4	0.30	2.20	0.49	0.10	0.219	0.492	4.36
110	0	0.18	1.43	0.41	0.03	0.109	0.575	2.98
	34.2	0.20	1.53	0.41	0.04	0.133	0.564	3.11
	68.4	0.32	2.53	0.52	0.12	0.222	0.564	4.33
		Whole-plot (A) and Sub-plot (B) Averages						
0	-	0.27	2.07	0.47	0.08	0.157	0.271	7.47
13.7	-	0.28	2.22	0.49	0.11	0.157	0.340	6.31
27.5	-	0.29	2.27	0.49	0.09	0.149	0.364	6.35
55	-	0.30	2.27	0.50	0.10	0.167	0.451	5.24
110	-	0.23	1.80	0.44	0.06	0.155	0.568	3.47
-	0	0.27	2.13	0.48	0.08	0.112	0.364	6.84
-	34.2	0.26	2.06	0.47	0.08	0.153	0.395	5.55
-	68.4	0.29	2.19	0.49	0.10	0.207	0.438	4.91
Grand Mean		0.27	2.12	0.48	0.09	0.157	0.399	5.77
LSD (0.05)	A	0.08	0.66	0.09	0.06	0.032 2/	0.082*	1.39*
	B	0.04	0.33	0.05	0.03	0.023*	0.052*	1.08*
	B/A	0.09	0.73	0.11	0.06	0.053	0.118	2.41
CV (%)	A	28.7	28.5	16.9	56.5	18.8	18.9	22.1
	B	19.2	20.3	13.3	40.7	20.0	17.4	24.5

1/ Applied as 100 micron droplets containing 20,000 ppm salinity.
2/ Significant at 95% level of probability.

Table 3. Nutrient contents of young soybeans treated with soil applied NaCl combined with aerial apray of cooling tower water on foliage. 1976

Treatments		Nutrient Contents						Metabolic Index
Soil Salts (A) kg/ha	Aerial Spray[1] (B) l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.30	2.80	1.83	1.10	0.104	0.076	33.62
	34.2	0.34	3.20	2.03	1.16	0.107	0.122	29.41
	68.4	0.35	3.13	2.08	1.43	0.131	0.181	22.44
13.7	0	0.33	3.07	2.04	1.33	0.114	0.086	34.48
	34.2	0.35	2.97	2.02	1.28	0.110	0.154	24.98
	68.4	0.38	3.20	2.07	1.56	0.111	0.201	23.11
27.5	0	0.33	2.73	1.97	1.27	0.117	0.142	25.07
	34.2	0.34	2.80	1.87	1.27	0.111	0.180	22.33
	68.4	0.36	3.03	2.06	1.65	0.138	0.250	19.17
55	0	0.33	2.83	1.98	1.49	0.115	0.183	22.38
	34.2	0.33	2.83	1.91	1.40	0.120	0.242	18.47
	68.4	0.35	3.17	2.16	1.62	0.126	0.290	17.89
110	0	0.33	3.00	2.09	1.35	0.116	0.213	20.63
	34.2	0.29	2.60	1.75	1.03	0.125	0.258	14.79
	68.4	0.36	3.10	2.27	1.58	0.141	0.256	18.56
		Whole-plot (A) and Sub-plot (B) Averages						
0	-	0.33	3.04	1.98	1.23	0.114	0.126	28.49
13.7	-	0.35	3.08	2.04	1.39	0.112	0.147	27.52
27.5	-	0.34	2.86	1.97	1.40	0.122	0.191	22.19
55	-	0.34	2.94	2.02	1.50	0.120	0.239	19.58
110	-	0.33	2.90	2.04	1.32	0.127	0.242	18.00
-	0	0.32	2.88	1.98	1.31	0.113	0.140	27.24
-	34.2	0.33	2.88	1.92	1.23	0.115	0.191	22.00
-	68.4	0.36	3.13	2.13	1.57	0.130	0.236	20.24
Grand Mean		0.34	2.96	2.01	1.37	0.119	0.189	23.15
LSD (0.05)	A	0.04	0.23	0.31	0.24	0.014	0.059*	4.97*
	B	0.02*[2]	0.23	0.14*	0.13*	0.007*	0.030*	2.34*
	B/A	0.05	0.52	0.32	0.29	0.016	0.068	5.22
CV (%)	A	10.0	7.1	14.2	15.8	10.8	28.9	19.7
	B	9.4	10.3	9.5	12.2	8.1	21.1	13.2

[1] Applied as 100 micron droplets containing 20,000 ppm salinity
[2] Significant at 95% level of probability

Table 4. Nutrient contents of soybeans at flowering after treatment with soil applied NaCl combined with aerial apray of cooling tower water on foliage. 1976.

Treatments		Nutrient Contents						Metabolic Index
Soil Salts (A) kg/ha	Aerial Spray (B) 1/ l/ha/day	P %	K %	Ca %	Mg %	Na %	Cl %	
0	0	0.33	2.20	1.76	1.12	0.117	0.102	25.12
	34.2	0.33	2.20	1.81	1.20	0.122	0.239	15.31
	68.4	0.35	2.27	1.91	1.07	0.129	0.349	11.68
13.7	0	0.35	2.07	1.98	1.13	0.132	0.108	23.53
	34.2	0.33	2.07	1.73	1.28	0.122	0.244	14.86
	68.4	0.34	1.93	1.86	1.36	0.131	0.358	11.26
27.5	0	0.32	1.83	1.81	1.24	0.112	0.159	19.35
	34.2	0.35	2.07	2.02	1.28	0.125	0.203	13.48
	68.4	0.26	1.67	1.71	0.73	0.125	0.353	9.46
55	0	0.31	1.97	1.79	1.22	0.120	0.235	15.05
	34.2	0.31	2.03	1.74	1.29	0.126	0.364	11.10
	68.4	0.33	2.23	2.01	1.24	0.140	0.469	9.57
110	0	0.30	1.77	1.86	1.16	0.126	0.307	11.52
	34.2	0.31	1.87	1.70	1.15	0.114	0.370	10.40
	68.4	0.31	1.67	1.73	1.27	0.125	0.474	8.55
		Whole-plot (A) and Sub-plot (B) Averages						
0	-	0.34	2.22	1.83	1.13	0.121	0.230	17.37
13.7	-	0.34	2.02	1.86	1.26	0.128	0.234	16.55
27.5	-	0.31	1.86	1.85	1.08	0.121	0.272	14.10
55	-	0.32	2.08	1.85	1.25	0.129	0.356	11.91
110	-	0.31	1.77	1.70	1.20	0.122	0.384	10.15
-	0	0.32	1.97	1.80	1.17	0.121	0.182	18.91
-	34.2	0.33	2.05	1.80	1.24	0.122	0.304	13.03
-	68.4	0.32	1.95	1.85	1.13	0.130	0.401	10.10
Grand Mean		0.33	1.99	1.82	1.18	0.124	0.296	14.01
LSD (0.05)	A	0.04	0.36	0.37	0.21	0.011	0.054* 2/	3.21
	B	0.02	0.19	0.15	0.14	0.029	0.042*	1.76*
	B/A	0.05	0.43	0.34	0.30	0.066	0.094	3.93
CV (%)	A	11.1	16.5	18.6	16.7	8.6	16.7	21.1
	B	8.8	12.6	10.9	15.1	31.1	18.7	16.5

1/ Applied as 100 micron droplets containing 20,000 ppm salinity.
2/ Significant at 95% level of probability.

Table 5. Yields of corn and soybeans treated with soil applied NaCl combined with aerial spray on foliage using cooling tower water for eight weeks. 1976.

Treatments		Corn		Soybean	
Soil Salts (A) kg/ha	Aerial Spray[1] (B) l/ha/day	bu/A	kg/ha	bu/A	kg/ha
0	0	115.5	7246	38.4	2580
	34.2	104.0	6524	38.2	2566
	68.4	108.4	6801	37.4	2512
13.7	0	109.9	6895	38.2	2566
	34.2	96.6	6061	36.9	2479
	68.4	110.1	6908	37.5	2520
27.5	0	127.9	8024	40.5	2721
	34.2	109.9	6895	35.2	2365
	68.4	109.2	6851	39.2	2633
55	0	119.2	7479	38.0	2620
	34.2	107.7	6757	38.6	2593
	68.4	111.4	7177	34.8	2338
110	0	113.8	7140	39.3	2640
	34.2	113.1	7096	38.2	2566
	68.4	114.7	7196	37.0	2486
Whole-plot (A) and Sub-plot (B) Averages					
0	-	109.3	6857	38.0	2553
13.7	-	105.5	6619	37.5	2519
27.5	-	115.6	7253	38.3	2573
55	-	112.7	7071	37.4	2513
110	-	110.5	6933	38.2	2566
-	0	117.2	7353	39.1	2627
-	34.2	104.2	6538	37.4	2512
-	68.4	110.7	6945	37.2	2499
Grand Mean		110.7	6945	37.9	2546
LSD (0.05)	A	12.6	791	1.8	121
	B	9.1*[2]	571	1.9	128
	B/A	20.3	1274	4.2	282
CV (%)	A	10.5	10.5	4.3	4.3
	B	10.8	10.8	6.5	6.5

1/ Applied as 100 micron droplets containing 20,00 ppm salinity.
2/ Significant at 95% level of probability.

Nitrogen Mineralization in a Manure Amended Evesboro Sandy Loam

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Purpose and Objectives

Antibiotics such as aureomycin and terramycin are routinely added to the feeds of many animals for the purposes of increasing weight gain and preventing disease. It has been found these drugs are excreted in the feces and urine of the animals. Upon disposal of these wastes on the soil, the antibiotics may exert an important effect on soil reactions governed by microorganisms.

The objective of this study was to determine the level of nitrogen mineralization occurring in an Evesboro sandy loam amended with manure from animals being fed antibiotic fortified grain.

Procedure

Nine beef cattle were fed grain fortified with either aureomycin, terramycin, or no antibiotics for a period of ten days. Antibiotics were administered to the cattle at a level of approximately 70 mg/head/day. Chemical and microbiological analyses were performed on fresh frozen homogenized manure samples collected during this period.

Manure collected on the tenth day of feeding was added to 25g samples of Evesboro sandy loam that had been previously air-dried, sieved, limed and fertilized. No nitrogen fertilizer was added to the soil. The application rate of the manure was 0.50g/25g soil (20 wet tons/acre) and 1.00g/25g soil (40 wet tons/acre). Samples were maintained at 60% water holding capacity throughout the sampling period at room temperature in the dark. On days 1, 7, 14, 17, 21, 24, 28, 45 and 59 samples were removed and analyzed for NH_4-N and NO_3-N levels and for pH.

Measurement of pH was made on a one:one soil sample-water mixture. Semi-micro Kjeldahl methods were used for NH_4-N and NO_3-N analysis.

Results

Mean values of the results of elemental and antibiotic analysis of the manure used in this study are shown in Table 1.

Throughout the experiment no significant differences were observed between the pH or ammonium levels of any of the antibiotic treatments at either the loading rate of 20 or 40 tons/acre. All samples did exhibit a decrease of approximately one-half pH unit through the course of the experiment. No differences are apparent in the nitrification rates at the loading rate of 20 tons/acre.

At application levels of 40 tons/acre differences appear by 45 days of incubation (Figure 1). At this time control manure amended soils contain 16.2 ppm NO_3-N, aureomycin manure amended soils 9.34 ppm NO_3-N and terramycin manure amended soils 17.0 ppm NO_3-N. Also, after 45 days of incubation the nitrate levels of the soils supplemented with the manure containing antibiotics become stationary, while the nitrate levels in soil with manure containing no antibiotics continue to climb. After 59 days of incubation the control level had reached 26.9 ppm NO_3-N, while the terramycin remained at 17.0 ppm NO_3-N and the aureomycin rose to 9.7 ppm NO_3-N.

The inhibiting effect does not appear until after 28 days of incubation. Such an effect could be due to differences in the organic nitrogen form of the manure, latent antibiotic effects, or differences in the C:N ratio.

Summary

At the highest level of application, inhibition of nitrification of the manure from cattle on antibiotic fortified feed was observed. Levels of

nitrate nitrogen in the soils with aureomycin and terramycin became stationary after 45 days, while levels of nitrate in the control continued to increase.

No differences between treatments were observed with the pH or NH_4-N levels at either application rate, or in NO_3-N levels at the 20 tons/acre application rate.

Table 1. Elemental and antibiotic analysis of manures from beef cattle receiving antibiotic fortified feed 1/

Feed Additive	Antibiotic (ug/g)	Total N (%)	NH_4-N (ug/g)	NO_3-N (ug/g)	P (%)	K (%)	Mg (%)	Na (%)
control	--	1.62	92.1	12.9	0.31	0.90	0.26	0.08
aureomycin	5.34	1.74	65.3	25.0	0.38	1.04	0.24	0.07
terramycin	11.29	1.50	62.3	30.6	0.44	1.18	0.22	0.13

1/ Mean of 9 values expressed on a dry weight basis

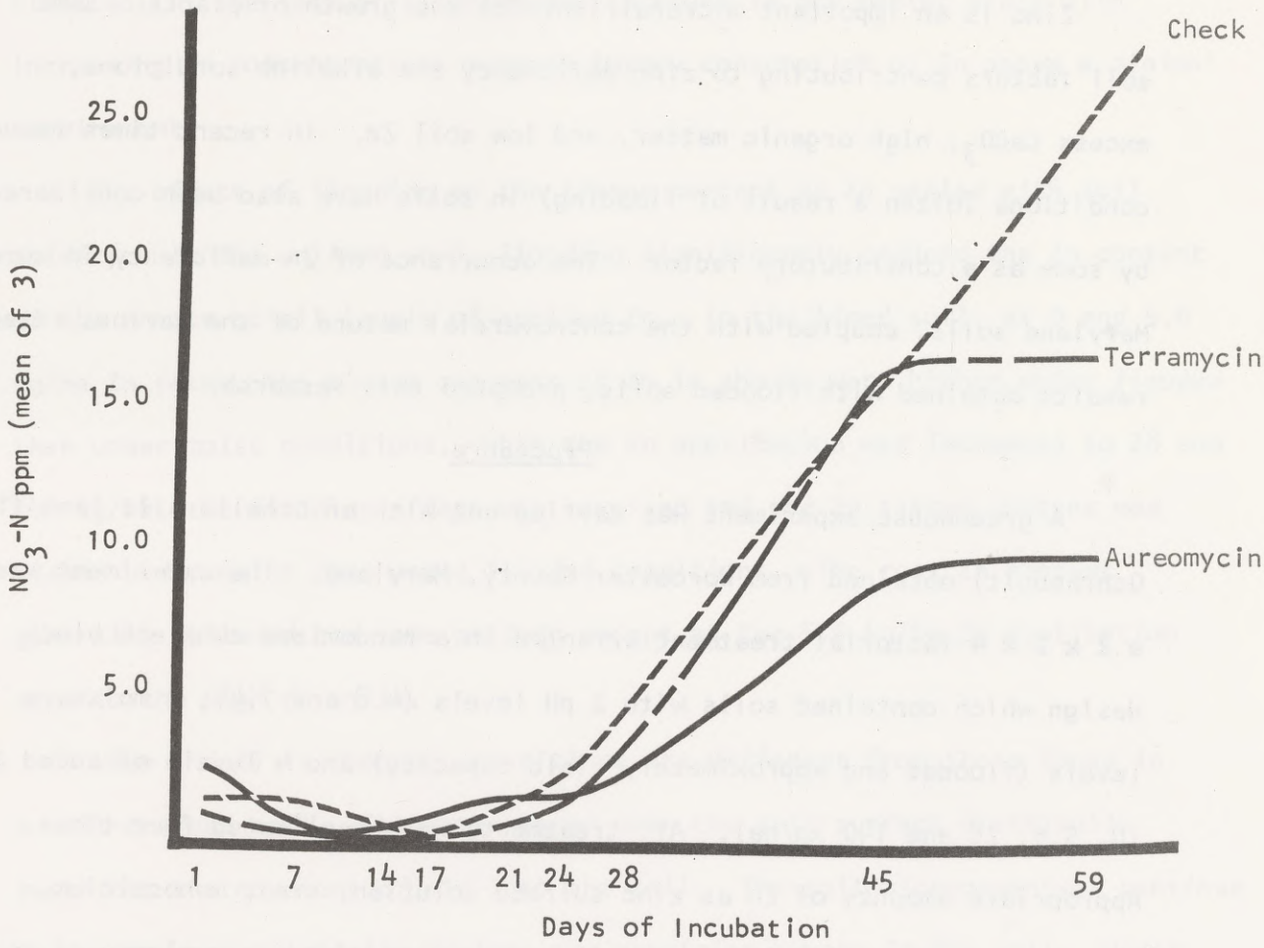

Figure 1. NO_3-N Levels over Time in Evesboro Sandy Loam Amended with Antibiotic-Affected Manure at a Rate of 40 tons/acre.

Zinc Uptake from Flooded Soils

V. Pavanasasivam and J. H. Axley

Purpose and Objectives

Zinc is an important micronutrient for the growth of plants. Some soil factors contributing to zinc deficiency are alkaline conditions, excess $CaCO_3$, high organic matter, and low soil Zn. In recent times reducing conditions (often a result of flooding) in soils have also been considered by some as a contributory factor. The occurrence of Zn deficiency in some Maryland soils, coupled with the controversial nature of the various research results obtained with flooded soils, prompted this research.

Procedure

A greenhouse experiment was carried out with an Othello silt loam (Typic Ochraquult) obtained from Worcester County, Maryland. The experiment was a 2 x 2 x 4 factorial treatment arranged in a randomized complete block design which contained soils with 2 pH levels (4.8 and 7.4), 2 moisture levels (flooded and approximately field capacity) and 4 levels of added Zn (0, 5.6, 28 and 140 kg/ha). All treatments were replicated four times. Appropriate amounts of Zn as zinc sulfate solution, urea, monocalcium phosphate, potassium sulfate, and limestone were added to a slurry of soil and water, stirred well, dried, crushed and sieved. Two-hundred and fifty grams of sieved soil were weighed into large culture tubes and seeded with Bluebelle rice and watered. After about one week of growth, one set of soils was flooded and the other set was maintained in a moist condition (approximately field capacity). Redistilled water was always used to water the plants. Plants were harvested 48 days after sowing. Shoots and roots were separated, washed, dried and analyzed for Zn content.

Results

The Zn content of both shoots and roots are given in Table 1. The Zn in the rice plants increased with increasing applications of Zn. These increases were more pronounced and consistent in the unlimed than in the limed soil. The lack of a continuous increase in dry matter yield with increasing Zn concentrations suggest luxury consumption of Zn above a minimal requirement.

The effect of flooding on the tissue content of Zn varied with soil acidity. In the unlimed soil, flooding significantly reduced the Zn content of the shoots at all levels of applied Zn. In the limed soil, at 0 and 5.6 kg/ha Zn rates, the tissue contents of Zn in shoots were higher under flooded than under moist conditions. When the Zn application was increased to 28 and 140 kg/ha, the flooding effect was reversed and the Zn tissue content was higher under moist than under flooded conditions. The root Zn content generally followed the same pattern except at the 5.6 kg/ha Zn application rate to the high pH soils.

When a soil is flooded, conditions are different from those found in a well-drained soil. The water layer over the soil surface drastically restricts the movement of air into the soil. The soil microorganisms continue to consume and eventually deplete the remaining oxygen in the soil. Under these conditions, the sulphate (SO_4^{--}) ions are converted to sulphide (S^{--}) ions if the soil is not too acid. Research evidence indicates that in the presence of sulphide ions, metallic ions such as Fe, Zn, Cu, etc. are precipitated and their availability to plants is significantly reduced.

In addition, flooding also causes the pH of an acid soil to rise and that of an alkaline soil to drop. These pH changes have a remarkable effect on Zn availability. In the unlimed low pH soils (pH 4.8), flooding resulted in an increase of pH and, with the effect of sulphide formation, caused a

significant reduction in Zn availability. In the limed soil however, the effect of precipitation of Zn as zinc sulphide was overcome by the slight decrease in pH at low levels of zinc sulphate application. When the zinc sulphate application was increased to 28 kg/ha sufficient sulphide ions may have been formed to cause a reduction in Zn availability.

Summary

A greenhouse experiment was conducted with an Othello silt loam to study the uptake of Zn under flooded soil conditions. The results indicate that flooding the soil reduced Zn availability in low pH soils. On the other hand, because of the lack of acidity, high pH soils have greatly reduced Zn availability and exhibit even further reductions in availability when flooded. This may be the effect frequently observed on the Eastern Shore and elsewhere in Maryland when corn is planted on heavily limed soils that were saturated with water throughout the winter. When these soils dry out, some of the unavailable zinc may slowly become available.

Table 1. Zn concentration in rice shoots and roots grown on Zn treated unlimed and limed Othello soils kept either moist or flooded.

Zn Treatment	pH 4.8		pH 7.4	
	Moist	Flooded	Moist	Flooded
kg/ha	ppm			
	Shoot			
0.0	122.8 gh*	57.1 f	14.6 a	18.8 b
5.6	206.0 i	126.9 h	28.7 c	35.5 d
28.0	408.0 k	287.6 j	50.6 ef	30.7 cd
140.0	797.6 m	656.9 l	105.7 g	43.9 e
	Root			
0.0	82.3 f	22.5 a	28.6 b	30.3 b
5.6	171.0 h	69.2 e	34.5 c	29.9 b
28.0	182.5 hi	176.6 hi	50.4 d	32.1 bc
140.0	476.6 j	201.2 i	108.7 g	45.2 d

*Statistical analysis performed on the log transformed data. Any two means (within shoot or root) not followed by the same letter are significantly different at 5% level.

Composting Organic Wastes by Suction Aeration Techniques

M. A. Ramirez, J. E. Foss and J. C. Patterson

Department of Agronomy and National Park Service

Purpose and Objective

Current practices in the treatment and disposal of urban-produced organic wastes are generally expensive and wasteful. Ironically, soils are often deficient in the very organic matter that is being disposed of at significant cost. Topsoil and many organic materials are often purchased at tremendous costs for the improvement, conditioning and renovation of many urban soils. Thus, treatment of organic waste by composting and the application of compost as a soil conditioner or amendment appears to be a beneficial and attractive utilization of these wasted organics.

This study was initiated to: (1) evaluate the composting potential of several mixtures of organic materials, (2) characterize the oxygen and temperature levels within the compost piles during the composting period, (3) evaluate the variability of temperature within a compost pile, and (4) to analyze and compare the compost mixtures for total and fecal coliforms.

Procedure

A static pile, forced aeration composting system based on procedures developed by USDA in Beltsville, Maryland was constructed for operation in Rock Creek Park, Washington, D. C.

Basically, the composting system consists of (1) mixing organic materials to specific proportions by a front end loader, (2) placing these mixtures over a layer of wood chips or other suitable organic material which contains a buried, perforated aeration pipe, (3) placing a cover of leaves approximately 12 inches thick over the pile, and (4) drawing air into and through the pile by an electric blower regulated to provide optimum aerobic composting conditions.

The following four mixtures of organic materials were initially composted:

	Materials	Volume (cubic yards per pile)
Compost I	digested sludge	5.5
	wood chips	11.0
	leaves	5.5
Compost II	leaves	11.0
	straw/horse manure	11.0
Compost III	leaves	7.5
	straw/horse manure	11.0
	wood chips	3.5
Compost IV	leaves	10.5
	paper	4.5
	straw/horse manure	7.5

These mixtures were composted in duplicate piles of approximately 22 cubic yards for 35 days. During this period the oxygen and temperature levels of the compost piles were monitored. A temperature transect at several depths was also conducted on 2 compost piles. Oxygen and temperature readings were taken at each end of the piles at a point approximately 1 meter below the pile surface and 1 meter above the ground surface (Figure 1). Compost samples were taken from an upper and lower location within the compost piles (Figure 1) 21 days after the compost piles reached 55°C. The samples were analyzed for total and fecal coliform. Following the composting process the products were evaluated for decomposition and future potential as a soil amendment. Compost mixtures I and II of the above formulations were selected for further evaluation as a soil conditioner in 'Kentucky-31', tall fescue, (Festuca arundinacea Schreb) turfgrass plots. These turfgrass plots were established on a Sassafras silt loam in Rock Creek Park.

Results

The static pile force aeration composting system was effective in rapidly decomposing most of the organic materials present in the compost mixtures. However, waste paper and large clumps of straw present in the compost piles did not decompose extensively during the 35 day composting period.

The oxygen levels present in the compost piles during the composting process are presented in Figure 2. Oxygen levels were generally maintained within a 5 to 15 percent range by timer-regulated blowers. The temperatures of the compost piles were maintained above 55°C for a period of not less than 21 days. The temperatures are presented in Figure 3. Temperature transects of two compost piles (Figures 4 & 5) indicated substantial temperature variation within the piles. The temperatures generally increased with increasing depth into the piles. However, the upper portion of the piles contained higher temperatures than the lower portion.

Coliform analysis on compost samples taken 21 days after the compost piles reached 55°C at the monitoring location indicated (Table 1) low counts of total coliforms present in the compost piles. Fecal coliform analyses indicate low counts of viable fecal coliforms present in the compost piles containing sludge and few, if any, viable fecal coliforms present in the other compost mixtures. Initial total coliform numbers of 5.2×10^7 for digested sewage sludge have been reported(1). The coliform data indicated that the upper section of the compost piles generally had lower counts than the lower section. This was apparently due to higher temperatures in the upper section. However, sampling location may play a significant role in the results obtained, due to the extreme heterogeneity of the compost piles and the variation of temperatures within the pile.

Summary

A compost operation was established in Rock Creek Park, Washington, D. C. and is currently a functioning maintenance operation. Organic waste materials which are produced or acquired by the park are presently being composted for park utilization.

Initially, four formulations of organic wastes were composted and monitored for temperature and oxygen levels. These parameters were generally maintained within specific levels during the composting process. Temperature transects of two compost piles indicated substantial temperature variation within the piles.

Lower counts of viable coliforms were observed in the upper section of the compost piles than in the lower section. Generally, low coliform counts were observed in both locations.

Further, research to physically and chemically characterize the final compost products and to evaluate their effects on 'Kentucky-31', tall fescue turfgrass plots is presently being conducted.

REFERENCES

(1) E. Epstein, G. B. Willson, W. D. Burge, D. C. Mullen, and N. K. Enkiri. 1976. A forced aeration system for composting wastewater sludge. Jour. Water Pollution Control Federation 48:688-94.

Table 1. Total and fecal coliform numbers in compost samples collected after 21 days of composting.

Compost mixture	Rep	Location‡ Sampled	Total coliform	Fecal coliform
			organisms/g*	organisms/g*
1	I	A	13	0
		B	4.4×10^3	7.6×10^2
	II	A	37	3.4
		B	8.3×10^4	5.6×10^4
2	I	A	3.3	0
		B	3.3	0
	II	A	0	0
		B	0	0
3	I	A	3	0
		B	3	3
	II	A	1.3×10^3	7.9×10^2
		B	0	0
4	I	A	0	0
		B	1.3×10^2	0
	II	A	0	0
		B	7.2	0

*Most Probable Number of organisms/g dry compost

‡Location A = uppersection of the pile (see Fig. 1)
B = lower section of the pile (see Fig. 1)

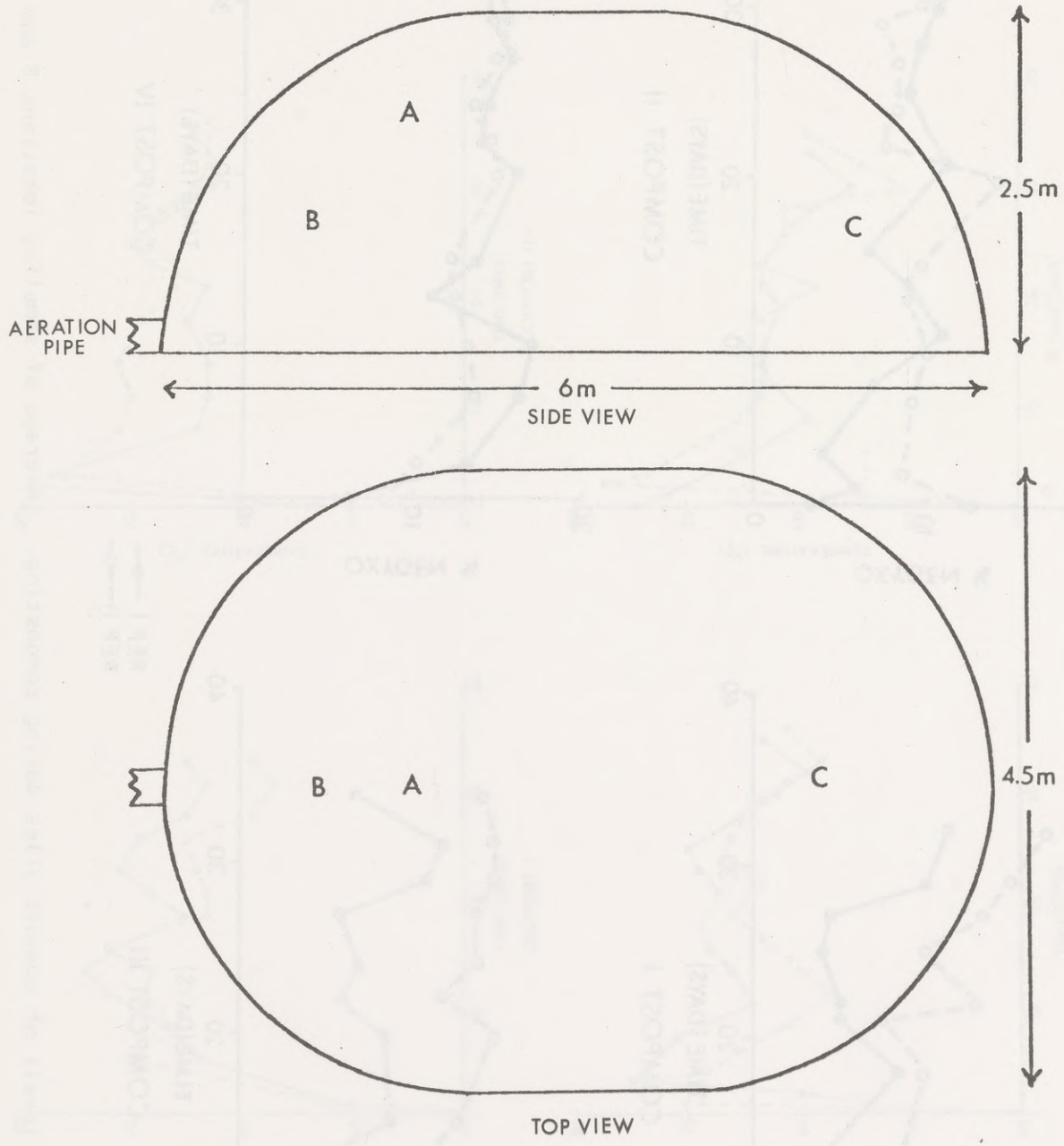

Figure 1. Sampling locations and dimensions of all the compost piles. Samples for coliform analysis were taken at locations A and B. Temperature and oxygen measurements were made at locations B and C.

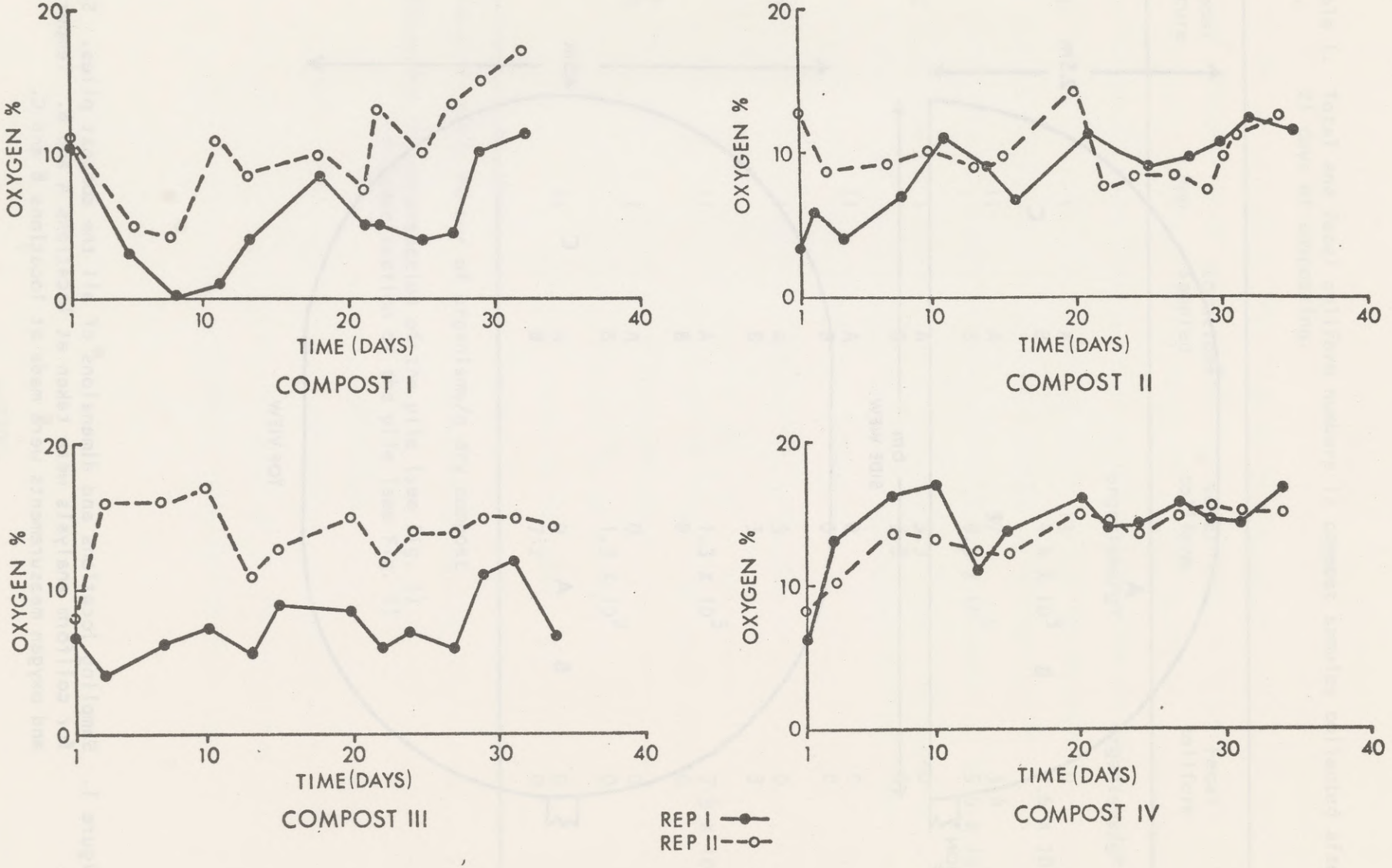

Figure 2. Oxygen levels of compost piles during composting. (Average of sampling locations B and C)

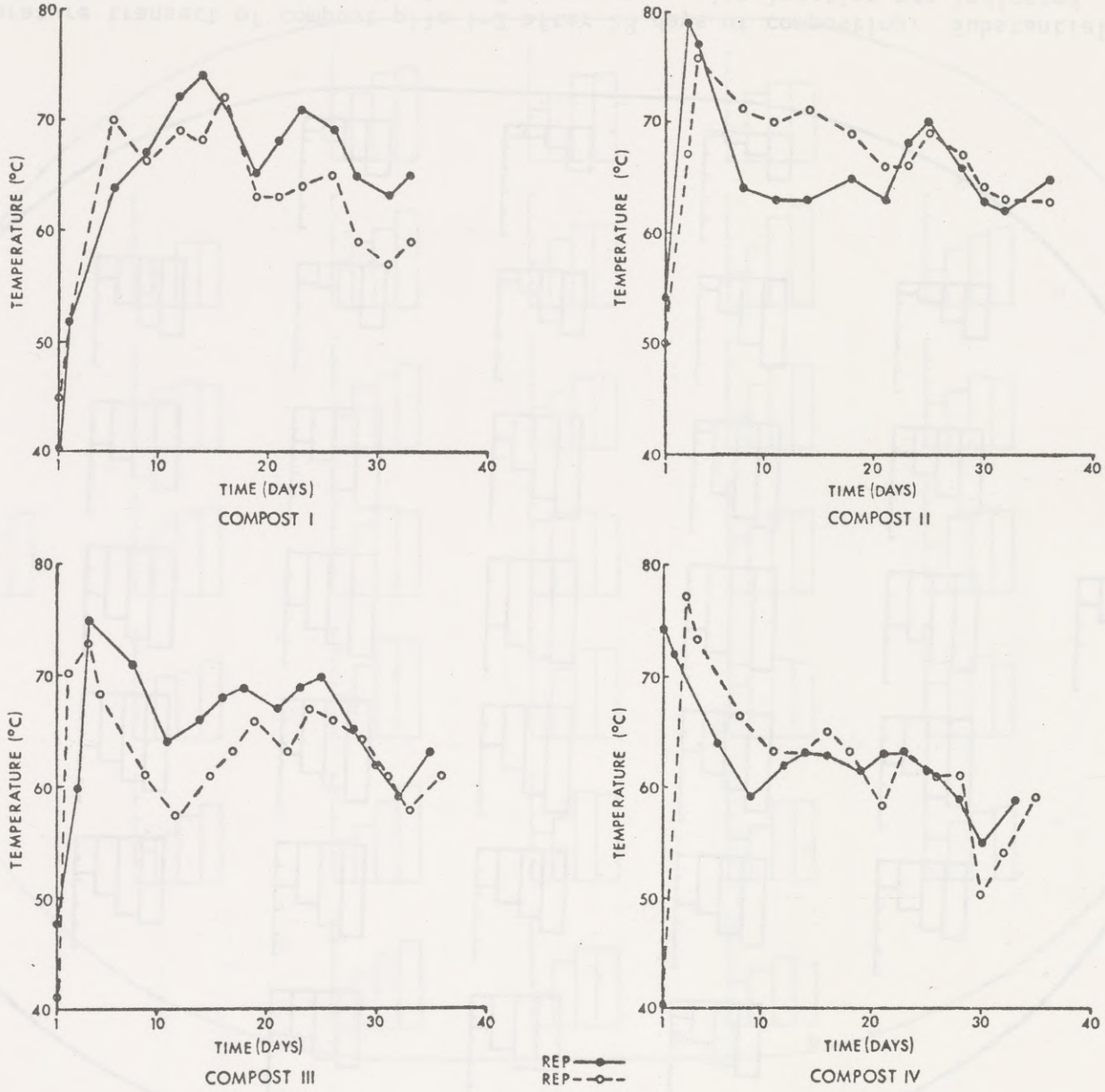

Figure 3. Temperature levels of compost piles during composting. (Average of sampling locations B and C)

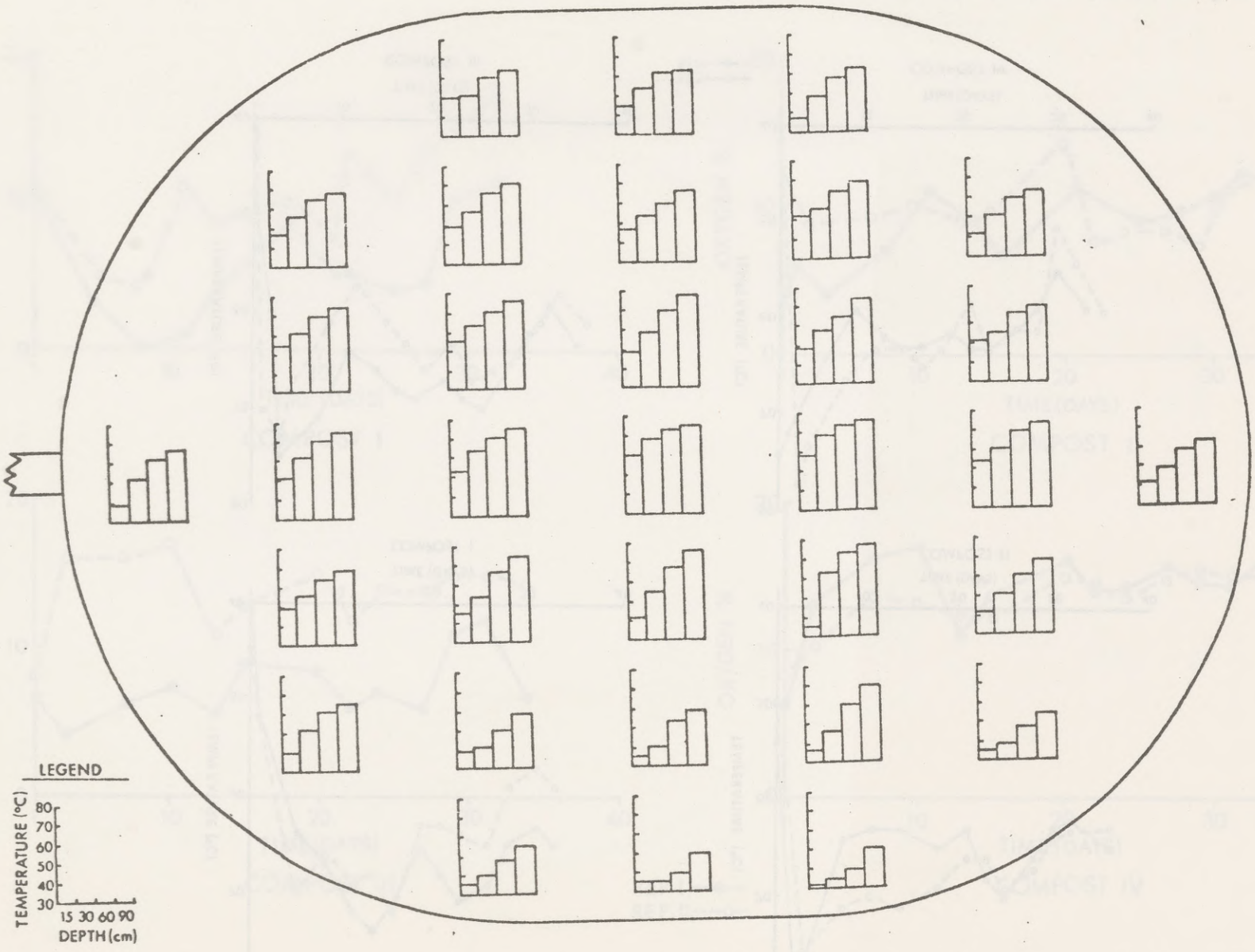

Figure 4. Temperature transect of compost pile I-2 after 28 days of composting. Substantial temperature increase with depth and considerable variation of temperature with location are indicated. Each bar graph is located at the sampling site where the temperatures were obtained.

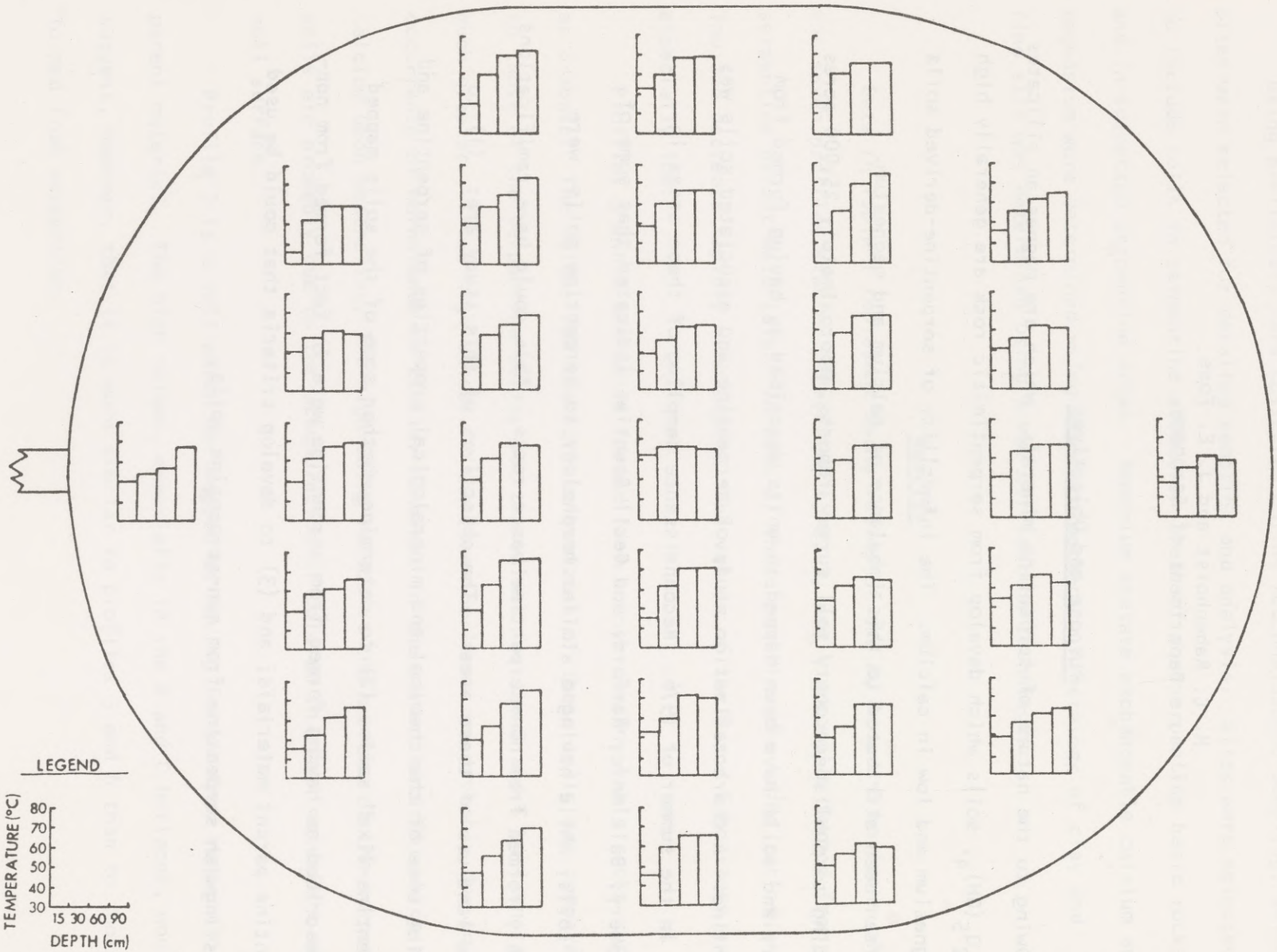

Figure 5. Temperature transect of compost pile II-1 after 14 days of composting. Substantial temperature increase with depth and considerable variation of temperature with location are indicated. Each bar graph is located at the sampling site where the temperatures were obtained.

Chemical and Mineralogical Examination of Serpentine and Associated Soils in Maryland

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Purpose and Objectives

Owing to the nature of serpentine minerals, which are magnesian silicates $Mg_3Si_2O_5(OH)_4$, soils which develop from serpentinitic rock are generally high in magnesium and low in calcium. The infertility of serpentine-derived soils has often been attributed to this imbalance of calcium and magnesium. According to published county soil survey reports, approximately 25,000 acres of Maryland soils have been mapped in units described as having formed from serpentine. A characterization study of serpentine and associated soils was begun in the summer of 1976. Reconnaissance sampling of these areas in Montgomery, Baltimore, Harford, and Cecil Counties indicated that some of these soils, while having a similar morphology to serpentine soils, were possibly formed from non-serpentine basic rocks. This could have ramifications on the land use of these areas. The objectives of this study are: (1) to describe some of the chemical and mineralogical properties of serpentine and "serpentine-like" soils; (2) to determine whether some of the soils mapped and described as having formed from serpentine were in fact formed from non-serpentine parent materials; and (3) to develop criteria that could be used to distinguish serpentine from non-serpentine soils.

Procedure

Using preliminary data collected during reconnaissance sampling, seven sites were selected for detailed sampling and analysis. Sites were selected to include soils in serpentine areas, in areas of non-serpentine basic rocks, and in suspected serpentine areas. Ammonium acetate exchangeable calcium and magnesium were determined using standard methods. Mineralogy of clay and fine silt was determined using X-ray diffraction techniques.

Results

Data in Table 1 represent Ca:Mg ratios of the A, B, and C horizons of the seven profiles studied. Profiles 1, 2, 3, and 4 are soils formed from serpentine parent materials. In each of these profiles the Ca:Mg ratios are low and decrease rapidly with depth. The values of the B and C horizons are especially low.

Profiles 5 and 6 are soils formed from non-serpentine basic rocks such as diabase. The values for the surface horizons of these soils are comparable to those of the serpentine soils, but the values for the B and C horizons are much greater. These high values in the lower horizons are probably due to the occurrence of hornblende or similar minerals in the parent material which release calcium upon weathering. The high Ca:Mg ratios at the surface of the serpentine soils are probably due to the accumulation of calcium in plant materials at the soil surface.

Profile 7 is a soil which was mapped as having formed from serpentinitic parent material. The high values, especially in the B and C horizons, would suggest, however, that it is more similar to profiles 5 and 6 than to those formed from serpentine.

Mineralogical interpretations for the fine silt (2-5μm) and coarse clay (0.2-2.0μm) fractions of the B2t horizons are given in Tables 2 and 3. Serpentine occurs in the fine silt and corase clay of profiles 2, 3, and 4 and in the fine silt fraction of profile 1, but is absent altogether from profiles 5, 6, and 7. Chlorite, which is chemically similar to serpentine, also occurs only in profiles 1, 2, 3, and 4. These data suggest more conclusively that profile 7 is not of serpentine origin.

Vermiculite occurs at moderate to high levels in the fine silt fractions and at high to dominant levels in the coarse clay fractions of all seven soils. Chlorite and mica in the parent material are the probable precursors of this vermiculite.

Summary

Due to a lack of chemical and mineralogical information, it appears that some soils in Maryland have been erroneously mapped and described as having formed from serpentine when the parent material actually is a non-serpentine basic rock. Ratios of exchangeable calcium to magnesium may be useful in distinguishing these soils. The Ca:Mg ratios for B and C horizons of serpentine soils are generally less than 0.20 and often below 0.10; ratios for associated non-serpentine soils are generally greater than 0.60.

Vermiculite in the clay and fine silt fractions is common to both the serpentine and non-serpentine soils studied. In those soils formed from serpentine parent materials, serpentine minerals occur in the fine silt fraction of the B horizon and often in the corase clay.

Table 1. Calcium : magnesium ratios of major horizons in seven profiles.

	Profile Number*						
Horizon	1	2	3	4	5	6	7
	Ca (meq/100g)/Mg(meq/100g)						
A1 or Ap	0.69	1.65	0.07	0.27	1.04	0.90	7.20
A2 or B1	0.23	0.20	0.04	0.06	0.74	0.61	3.48
B2t	0.11	0.03	0.02	0.02	0.70	0.45	0.75
C	0.04	0.04		0.01	0.90	0.96	0.60

*1 - Aldino silt loam, Montgomery County
2 - Chrome silt loam, Baltimore County
3 - Chrome silt loam, Harford County
4 - Chrome silt loam, Cecil County
5 - Iredell silt loam, Montgomery County
6 - Kelly silt loam, Harford County
7 - Aldino silt loam, Harford County

Table 2. Semi-quantitative interpretation of mineralogy of fine silt (2-5μm) from B2t horizons of seven profiles.

Profile	Relative Quantity* of Various Minerals#							
	Fl	Qr	Mi	Vr	Mt	Chl	Kl	Serp
1	X	X	X	XX	-	XXX	-	XX
2	X	X	XX	XX	-	X	-	X
3	X	X	XX	XX	X	X	-	XXX
4	X	XX	XX	XXX	-	XX	-	XXX
5	X	XX	X	XXX	XX	-	X	-
6	X	XX	XX	XXX	-	-	XX	-
7	-	XX	X	XX	-	-	XXXX	-

* X - low amount,< 10%
XX - moderate amount, 10 - 30%
XXX - high amount, 30 - 70%
XXXX - dominant mineral,>70%

Abbreviations: Fl - feldspar; Qr - quartz; Mi - mica; Vr - vermiculite; Mt - montmorillonite; Chl - chlorite; Kl - kaolinite; Serp - serpentine

Table 3. Semi-quantitative interpretation of mineralogy of coarse clay (0.2-2.0μm) from B2t horizons of seven profiles.

Profile	Relative Quantity of Various Minerals							
	Fl	Qr	Mi	Vr	Mt	Chl	Kl	Serp
1	-	X	-	XXX	-	XXX	-	-
2	-	X	XX	XXX	X	XX	-	XXX
3	-	X	XX	XXX	X	XX	-	XXX
4	X	X	-	XXX	-	XX	-	XX
5	-	-	-	XXXX	X	-	X	-
6	X	X	XX	XXX	-	-	XXX	-
7	-	-	-	XXX	XX	-	XXX	-

Corn Production and Heavy Metal Content as Influenced by Sewage Sludge Application and Soil Temperature

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Purpose and Objectives

Significant amounts of sewage sludges are available for application to agricultural land under diverse climatic conditions. These sludges are high in nitrogen and phosphorus and are potentially valuable as a source of plant nutrients. The organic matter of the sludge may also be valuable as a soil conditioner. Unfortunately, high amounts of zinc, copper, cadmium, nickel, and lead can also occur and be detrimental to plant growth and to livestock and/or man when these plants are consumed. Proper soil and crop management is essential to avoid problems associated with heavy metals found in sludge.

The objectives of this study were: (1) to evaluate the effects of temperature on corn growth and metal uptake from sewage sludge, (2) to determine zinc, copper, cadmium, nickel, and lead uptake of corn from soil amended with sewage sludge, (3) to evaluate the effects of sewage sludge application on corn growth. This report deals with results of the second year of a study initiated in 1975.

Procedures

A split-plot experiment, established in 1975, to evaluate the effects of temperature and sludges on corn had temperature regimes (whole plots) of 35C, 27C, 16C, and ambient and was maintained on plots 4.5 by 1.8 M and sludge rates (sub-plot) of 0, 56, and 112 dry metric tons/ha were applied to plots 1.5 by 1.8 M. Sludge rates were obtained by mixing digested sludge with a Sassafras silt loam soil with a pH of 5.8. The Cu, Cd, Ni, Pb, and

Zn contents of the sludge were 2200, 16, 710, 140, and 4400 ppm, respectively, on an air dry basis.

On May 14, 1976, XL-43 field corn was planted into each sub-plot in rows 50 cm apart and at a distance of 5 cm within rows. Plants were later thinned to give a population of 21 plants per plot area. Tensiometers were used to monitor moisture levels and whole temperature plots were irrigated when necessary.

The corn plots were harvested when the corn grain was in the hard dent stage. The 35C plots were harvested on 9/17/76, 27C on 9/24/76, 16C on 10/14/76, and ambient on 10/11/76. Stover and grain weights were taken and samples obtained for elemental analyses. Ear leaves, stover, and grain were analyzed using an atomic absorption spectrophotometer for Zn, Cu, Cd, Ni, and Pb.

Results

As reported in 1975, soil temperature and sewage sludge application had significant effects on growth and yield of field corn in 1976 (Tables 1, 2, and 3). Unlike 1975 results, temperatures above ambient resulted in significant increases in grain and stover yields. A below ambient soil temperature of 16C was found to significantly reduce grain and stover yields and the largest increases in yield were observed as soil temperature increased from 16C to ambient. Plants were taller, had more leaves and matured earlier at 35 than at 16C.

The effects of sludge application were more pronounced in 1976 than in 1975. Check plots (zero sludge treatment) had significantly lower grain yields at all temperatures than those to which sewage sludge was applied. Stover yields were also lower. Plant height increased significantly as sludge rate increased.

A significant increase in the Zn content of corn ear leaves, grain, and stover occurred as sludge application rate increased (Table 4). Ear leaves and stover had significantly lower concentrations when grown on plots receiving the 16C soil temperature treatment than at other temperatures. Soil temperature had no significant effect on the levels of Zn found in the grain.

Soil temperature had no significant effect on the Cu content of grain or stover (Table 5). Significantly higher ear leaf concentrations occurred at soil temperatures of 27 and 35 than at 16C or ambient. Sludge application had no significant effect on stover copper levels, but did result in significant increases in Cu levels in the corn ear leaf and grain.

Cd levels in the corn ear leaves were significantly higher at 35C than at lower temperatures (Table 6). Cd levels in the grain were very low but were significantly higher at 16C and ambient temperatures than at 27 and 35C. Stover Cd levels were not significantly affected by soil temperatures. For ear leaf and grain, sludge application resulted in significantly higher levels of Cd than in untreated plots.

Stover levels of Pb were unaffected by soil temperature but were significantly lower at the 112 metric ton rate than at zero sewage sludge (Table 7). Ear leaf levels were highest from plots subjected to soil temperatures of 16C, which received no sludge amendment.

Soil temperature had no significant effect on Ni levels in the corn stover (Table 8). Grain concentrations were significantly higher when grown at 35C. Ear leaf and grain levels of Ni were significantly higher from plots amended with 112 metric tons per hectare than from unamended plots.

Summary

Corn at 16C was expected to have depressed growth rates and yields

since corn is a warm season plant with optimum yields occurring from 24 to 30C. The increased yields of grain and stover from plants grown at above ambient soil temperatures can be related to the early planting date and an unusually cool spring. The higher treatment temperatures during seedling development probably increased final yields. The economical feasibility of soil heating to increase corn yields is still questionable.

The beneficial aspects of sewage sludge as a supplier of plant nutrients and organic matter were demonstrated by the increased grain and stover yields from amended plots.

The variable results for metal concentrations can be related to the effects of dry matter dilution on concentration and to the lack of translocation of heavy metals, especially Cu, Pb, and Ni, to aerial portions of the corn plants. As dry matter production increases, if uptake does not increase at an equal rate then concentrations can decrease. Concentrations are increased by a stunting of plant growth such as occurred for check plots. Although plant metabolic activity and uptake mechanisms, diffusion, mass flow, and root interception are increased at higher soil temperatures, increased metal concentrations were not always observed in plant material.

Table 1. Average stover dry weights of corn grown in soil amended with three rates of sludge and subjected to four soil temperature regimes.

Soil Temperature	Sludge Application Rate Metric T/ha			
	0	56	112	Average
	Kg/plot			
16C	0.54 f*	0.66 ef	0.60 ef	0.60 Z
Amb.	0.83 de	0.93 cd	1.38 ab	1.04 Y
27C	0.95 cd	1.18 bc	1.42 ab	1.19 XY
35C	1.21 b	1.44 ab	1.53 a	1.39 X
Average	.88 C	1.05 B	1.23 A	

* Means within columns and rows followed by the same letter are not significantly different at the .05 level; capital letters are for main effects.

Table 2. Average grain dry weights of corn grown in soil amended with three rates of sludge and subjected to four temperature regimes.

Soil Temperature	Sludge Application Rate Metric T/ha			
	0	56	112	Average
	Kg/plot			
16C	0.75 f	1.33 de	1.36 de	1.15 Z
Amb.	1.15 ef	2.03 c	2.20 abc	1.79 Y
27C	1.48 de	2.18 bc	2.58 a	2.08 X
35C	1.47 d	2.34 ab	2.64 a	2.15 X
Average	1.21 C*	1.97 B	2.20 A	

* Means within columns and rows followed by the same letter are not significantly different at the .05 level; capital letters are for main effects.

Table 3. Average plant height of corn grown in soil amended with three rates of sludge and subjected to four temperature regimes.

Soil Temperature	Sludge Application Rate Metric T/ha			
	0	56	112	Average
	- - - - - - - - - - - - - - - Kg/plot - - - - - - - - - - - - - - -			
16C	1.74 NS	1.76	1.79	1.77 Z
Amb.	1.93	2.02	2.05	2.00 Y
27C	2.05	2.15	2.23	2.15 X
35C	2.11	2.26	2.27	2.21 W
Average	1.96 c*	2.05 b	2.09 a	

* Means within columns and rows followed by the same letter are not significantly different at the .05 level; capital letters are for main effects.

Table 4. Effects of soil temperature and sewage sludge application on the average Zn concentrations in corn ear leaves, stover, and grain, 1976.

Soil temperature	Sludge Rate	Ear Leaf	Grain	Stover
	M T/ha	- - - - - - - ppm - - - - - - -		
16C	0	18 f[1/]	19 d	19 d
	56	73 e	32 b	237 a
	112	104 d	36 ab	312 a
	Average	65 C	29 A	189 B
22C (Ambient)	0	27 f	27 c	44 c
	56	109 d	37 ab	258 a
	112	144 c	40 a	291 a
	Average	93 B	35 A	198 A
27C	0	22 f	25 cd	57 c
	56	113 cd	31 b	216 b
	112	206 a	40 a	320 a
	Average	113 A	32 A	198 A
35C	0	26 f	27 c	47 c
	56	137 c	37 ab	197 b
	112	180 b	37 ab	233 a
	Average	114 A	33 A	159 A
Average	0	23 C	24 C	42 C
	56	108 B	34 B	227 B
	112	158 A	38 A	289 A

1/ Values within each plant material category followed by the same letter are not statistically different at the 5% level of significance as determined by Duncan's Multiple Range Test. Capital letters denote main effects.

Average values for sludges are across all soil temperatures.

Table 5. Effects of soil temperature and sewage sludge application on the average Cu concentrations in corn ear leaves, stover, and grain, 1976.

Soil temperature	Sludge rate	Ear leaf	Grain	Stover
	M T/ha	- - - - - - - ppm - - - - - - -		
16C	0	6.3 de[1/]	1.61 a	3.0 a
	56	5.9 de	1.62 a	4.8 a
	112	8.1 cd	1.73 a	4.1 a
	Average	6.7 B	1.65 A	3.9 A
22C (Ambient)	0	5.4 e	1.60 a	3.8 a
	56	7.1 de	1.80 a	4.9 a
	112	8.0 cd	1.77 a	3.6 a
	Average	6.8 B	1.72 A	4.1 A
27C	0	5.0 e	1.63 a	4.5 a
	56	9.6 bc	1.77 a	5.1 a
	112	12.3 ab	1.62 a	4.3 a
	Average	9.0 A	1.64 A	4.6 A
35C	0	6.2 de	1.55 a	4.9 a
	56	11.0 ab	1.95 a	4.6 a
	112	11.8 ab	1.88 a	4.4 a
	Average	9.7 A	1.70 A	4.6 A
Average	0	5.7 B	1.6 B	4.0 A
	56	8.4 BA	1.7 A	4.8 A
	112	10.1 A	1.7 A	4.1 A

1/ Values within each plant material category followed by the same letter are not statistically different at the 5% level of significance as determined by Duncan's Multiple Range Test. Capital letters denote main effects.

Average values for sludges are across all soil temperatures.

Table 6. Effects of soil temperature and sewage sludge application on the average Cd concentrations in corn ear leaves, stover, and grain, 1976.

Soil temperature	Sludge rate	Ear leaf	Grain	Stover
	M T/ha	- - - - - - - - ppm - - - - - - - -		
16C	0	0.13 a[1/]	.05 a	0.18 c
	56	0.35 a	.10 a	0.36 b
	112	0.33 a	.10 a	0.55 ab
	Average	0.27 B	.09 A	0.36 A
22C (Ambient)	0	0.21 a	.07 a	0.46 a
	56	0.43 a	.10 a	0.78 a
	112	0.44 a	.12 a	0.44 b
	Average	0.36 B	.09 A	0.56 A
27C	0	0.25 a	.04 a	0.31 b
	56	0.36 a	.09 a	0.61 ab
	112	0.36 a	.07 a	0.32 b
	Average	0.32 B	.07 B	0.41 A
35C	0	0.39 a	.06 a	0.41 b
	56	0.60 a	.07 a	0.59 ab
	112	0.66 a	.10 a	0.38 b
	Average	0.55 A	.07 B	0.46 A
Average	0	.25 B	.06 B	.34 B
	56	.44 A	.09 A	.59 A
	112	.45 A	.10 A	.42 B

1/ Values within each plant material category followed by the same letter are not statistically different at the 5% level of significance as determined by Duncan's Multiple Range Test. Capital letters denote main effects.

Average values for sludges are across all soil temperatures.

Table 7. Effects of soil temperature and sewage sludge application on the average Pb concentrations in corn ear leaves, stover, and grain, 1976.

Soil temperature	Sludge rate	Ear leaf	Grain	Stover
	M T/ha	- - - - - - - - ppm - - - - - - - -		
16C	0	3.01 a[1/]	.08 a	2.67 a
	56	2.31 a	.10 a	2.57 a
	112	2.33 a	.91 a	2.24 a
	Average	2.55 A	.10 A	2.49 A
22C (Ambient)	0	1.91 a	.04 a	2.61 a
	56	1.17 a	.08 a	2.65 a
	112	1.11 a	.06 a	1.85 a
	Average	1.40 BC	.06 B	2.37 A
27C	0	0.96 a	.08 a	3.60 a
	56	1.09 a	.13 a	2.71 a
	112	1.14 a	.06 a	1.70 a
	Average	1.06 C	.09 A	2.67 A
35C	0	1.62 a	.04 a	2.10 a
	56	1.30 a	.05 a	2.13 a
	112	1.51 a	.09 a	1.62 a
	Average	1.48 B	.06 B	2.61 A
Average	0	1.88 A	.06 A	3.2 A
	56	1.47 B	.09 A	2.5 AB
	112	1.52 B	.08 A	1.9 B

1/ Values within each plant material category followed by the same letter are not statistically different at the 5% level of significance as determined by Duncan's Multiple Range Test. Capital letters denote main effects.

Average values for sludges are across all soil temperatures.

Table 8. Effects of soil temperature and sewage sludge application on the average Ni concentrations in corn ear leaves, stover and grain, 1976.

Soil temperature	Sludge Rate	Ear Leaf	Grain	Stover
	M T/ha	- - - - - - - - ppm - - - - - - - -		
16C	0	0.58 a[1/]	0.28 a	0.61 a
	56	0.64 a	0.83 a	0.67 a
	112	0.54 a	1.27 a	0.96 a
	Average	0.59 B	0.79 B	0.74 A
22C (Ambient)	0	1.08 a	0.53 a	0.61 a
	56	1.47 a	0.89 a	0.93 a
	112	1.83 a	0.99 a	0.63 a
	Average	1.46 A	0.80 B	0.72 A
27C	0	1.09 a	0.40 a	0.48 a
	56	1.02 a	0.78 a	0.87 a
	112	1.53 a	0.95 a	0.58 a
	Average	1.21 AB	0.71 B	0.64 A
35C	0	0.73 a	.71 a	0.61 a
	56	0.96 a	.87 a	1.13 a
	112	1.15 a	1.43 a	0.62 a
	Average	0.95 AB	1.00 A	0.79 A
Average	0	.87 B	.48 C	.57 B
	56	1.02 AB	.84 B	.90 A
	112	1.26 A	1.16 A	.69 B

1/ Values within each plant material category followed by the same letter are not statistically different at the 5% level of significance as determined by Duncan's Multiple Range Test. Capital letters denote main effects.

Average values for sludges are across all soil temperatures.

Influence of Organic Animal Wastes on the Leaching of Calcium from Soil

P. A. Snow and J. H. Axley

Purpose and Objectives

Since manure enhances the biological and chemical transformations occurring within the soil, it may lead to increased nutrient mobility in the soil. The purpose of this investigation was to study this effect on calcium mobility and the lime requirement of the soil.

Procedure

A Giddings hydraulic soil coring and sampling machine was used to obtain sixteen 4 inch x 32 inch Sassafras sandy loam soil cores. The cores were fitted into 4 inch PVC pipe with the base of each column sealed with a plexiglass plate having a drainage tube in the center. The soil columns were then leached with a total of 83 inches of distilled water or poultry processing waste water. The leachates from these columns were collected and analyzed for calcium and pH; and the soil was analyzed in 4 inch increments after leaching.

Finally, field soil samples were collected from areas irrigated with poultry waste water for 2 years and 10 years, from a field irrigated with liquefied hog manure for 3 years, from the floor of a 40-year-old chicken house, and from untreated soils surrounding these areas and analyzed for calcium and pH.

Results

The application of 83 inches of waste water with a concentration of 9.5 ppm calcium contributed to the soil columns an equivalent of 445 lbs of limestone per acre. However, 2705 lbs of limestone per acre were leached

from these columns. In comparison, only 620 lbs of limestone were removed by leaching with an equivalent amount of distilled water. This point is illustrated by the calcium content of the leachates from the distilled water and waste water treated columns (Fig. 1). Calcium in the leachates declined as distilled water was added, whereas the calcium concentration increased with increased additions of waste water. In brief, the waste water caused a translocation of calcium from the surface soil to the subsoil. For example, there was a 100 lbs/A calcium increase in the 16 to 20 inch depth. This loss of calcium from the surface was also characterized by a reduction in the pH of the surface soil (Table 1) and an increase in pH of the leachates.

Calcium removal from field soils by the addition of manures and other readily decomposable organic materials was shown by soil test results (Table 2). Irrigation with poultry processing waste water for ten years decreased the weak acid-extractable calcium in a Sassafras sandy loam from 255 to 170 lbs/A in the 36-40 inch depth with similar drastic reductions in the soil above this depth (Table 2). This effect was also dramatized by a lowering of the soil pH as much as 1.4 units at the 4 to 8 inch depth.

In a field irrigated for two years with poultry waste water, the losses were not as great. However, the extractable calcium levels were decreased throughout 48 inches of the soil (1).

In a Lakeland loamy sand field irrigated for three years with hog manure containing 1.4% calcium, accumulation in the surface soil occurred even though leaching losses were high. When the Lakeland loamy sand soil was used as the floor of an active chicken house for forty years, only a little movement of calcium into the soil was noted (1).

Summary

Under natural environmental conditions, calcium was found to move faster and farther in soils in the presence of active organic matter than in its absence. Therefore, when manures are applied to soil, additional lime may be required to offset the enhanced calcium losses from the soil, unless manures are richly endowed with calcium.

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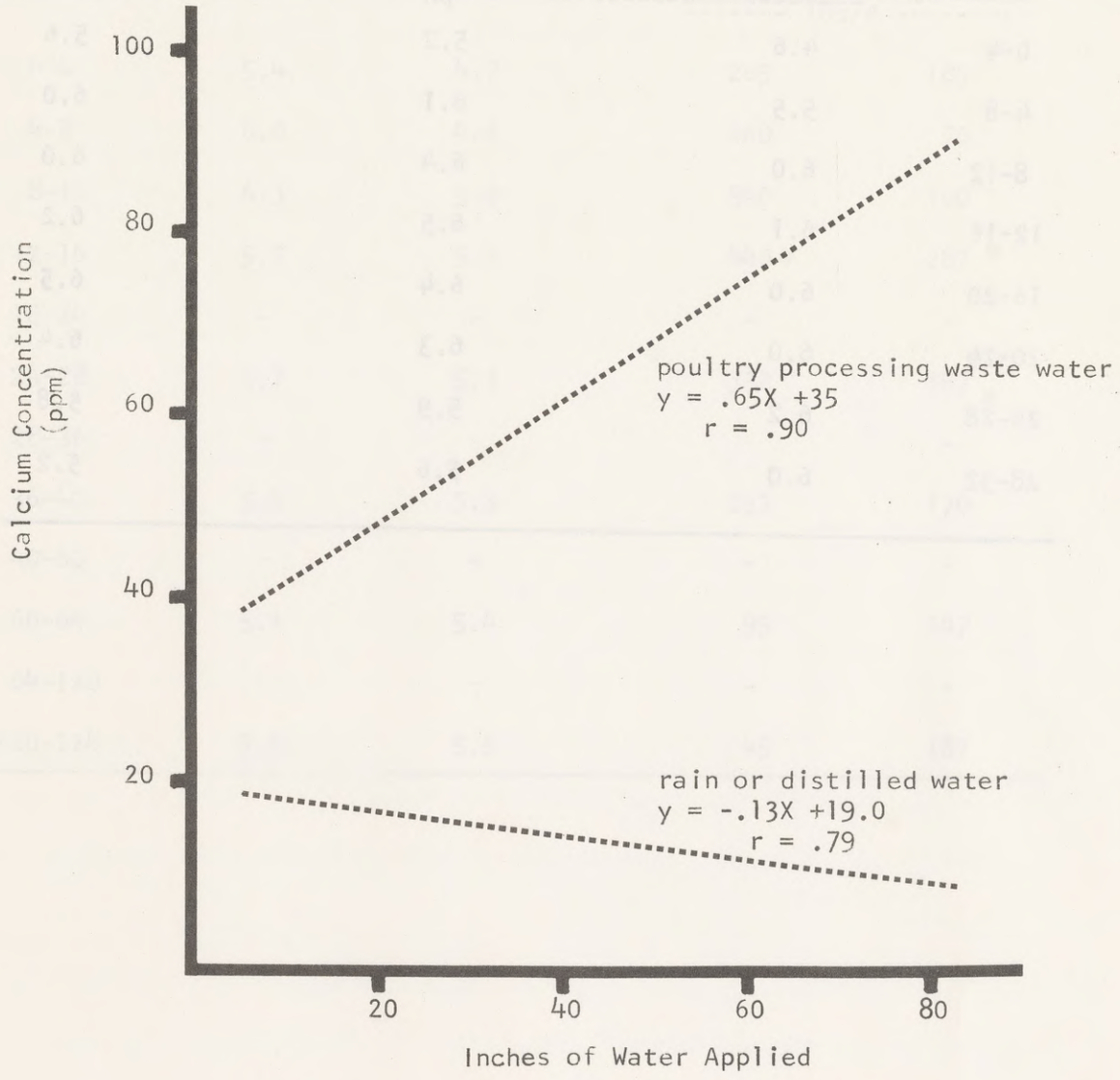

Fig. 1. Calcium concentration of waters after percolating through 32 inch Sassafras sandy loam columns.

Table 1. The effect of 83 inches of either poultry processing waste water or distilled water on the acidity (pH) of 32 inches of a Sassafras sandy loam.

Soil Depth	Waste Water	Distilled Water	Untreated
	pH		
0-4	4.6	5.2	5.6
4-8	5.5	6.1	6.0
8-12	6.0	6.4	6.0
12-16	6.1	6.5	6.2
16-20	6.0	6.4	6.5
20-24	6.0	6.3	6.4
24-28	6.2	5.9	5.8
28-32	6.0	5.6	5.2

Table 2. The level of acidity (pH) and calcium in a Sassafras sandy loam treated with poultry processing waste water for ten years as related to depth.

Soil Depth (in.)	pH		Extractable Calcium	
	Untreated	Treated	Untreated	Treated
			------- lbs/A ---------	
0-4	5.4	4.7	265	185
4-8	6.0	4.6	460	70
8-12	6.3	5.0	540	100
12-16	5.9	5.0	440	287
16-24	-	-	-	-
24-28	5.7	5.3	332	357
28-36	-	-	-	-
36-40	5.4	5.3	255	170
40-60	-	-	-	-
60-64	5.1	5.4	95	147
64-120	-	-	-	-
120-124	5.2	5.5	45	187

MAPPING OF HIGHLY MAN INFLUENCED SOILS IN WASHINGTON, D.C.

C. E. Stein, D. S. Fanning and J. C. Patterson

Purpose and Objectives

Examinations of soils in man-deposited materials in Washington, D.C. revealed a high degree of soil variability over short distances. Since preliminary work indicated that approximately 40% of the open land in the District (mainly park land) had soils developed in man-deposited materials an in-depth study was needed (as part of the soil survey of the District, 10) to characterize and classify these soils. The man-deposited materials, in the study area (Fig. 1), consisted primarily of river dredgings from the Potomac River and miscellaneous fills. The miscellaneous fills were a mixture of materials from various sources and usually included artifacts such as rubble from torn down buildings.

This report describes the mapping which was done in conjunction with an overall soil survey of the District of Columbia (10). The specific objectives were to:

1. Define and delineate the type, extent and origin of fill materials found within the study area,
2. Determine field characteristics and landscape relationships for recognizing, defining and mapping soils at a detailed level,
3. Develop taxonomic units, soil mapping units, special spot symbols and a mapping legend for the range of soils encountered, and
4. Prepare a detailed soil map of the study area.

Subsequent reports will deal with an evaluation of the mapping, the characterization and variability of selected morphological, physical and chemical properties within certain mapping units and the classification of the soils.

Procedures

In a reconnaissance survey the areas to be studied were cartographically defined (Fig. 2). Existing data from the Ecological Services Lab (8), Metro (4), Bartlett Tree Study (2), geological reports and maps (3, 12) and personal references (7) were collected and examined to provide information concerning the study area. Also historical records, maps and pictures (1, 5, 6, 9, 11) were examined to determine the type, extent and origin of the fill materials. These records were also used to establish probable dates of deposition and maximum age of the deposits of fill.

Some of the different kinds of soils were studied, described and sampled from pits or available excavations. Most of the soils, however, were examined at random sites from auger holes. Often the soil was too compact, too dry, or had too many coarse fragments to auger to desired depths. In these cases a tiling spade was used to supplement the auger in examining the soils. Transparent overlays were used with aerial photographs (1:12000 scale) to record the location examination sites and tentative soil boundaries. Sites were numbered consecutively and notes were taken at each site. Field characteristics and criteria that helped in consistent recognition of fill materials were recorded. Transects were made to determine whether soil-landscape relationships existed that would help in detailed mapping. Where some relationships were hypothesized, boundaries were sketched. These were then checked by observing the soil in auger holes along transects and or at random sites within the delineation. The use of various spot symbols was also evaluated. As the survey progressed, some additional pits were dug and the soil was described and sampled. The variability of various morphological and physical properties within a pedon was evaluated from these pits. Laboratory data including pH, organic matter content, bulk densities, particle size analysis

and coarse fragment percentages were collected for selected pedons. The collected data were used to develop taxonomic concepts and to set up taxonomic units and associated soil mapping units. Final selection of appropriate spot symbols, taxonomic units and associated mapping units was completed and then incorporated into a detailed identification mapping legend (Table 1).

In the detailed mapping the same base maps (1:12000 scale), with the tentative boundaries sketched from the reconnaissance survey, were used. The soils were examined along transects and where the soil pattern was known to be complex. The nature of most of the fill material and the generally complex soil pattern required a greater number of observations per acre than in most detailed soil surveys. Because of this and the interest in assessing practicality of mapping such soils, the detailed survey was divided into two sections. One section, which contained East and West Potomac Park, the Washington Monument Grounds and parts of the Mall, was mapped at a higher level of intensity (i.e., more observations per acre). The other section, which contained Columbia Island was mapped by more normal mapping methods using soil-landscape relationships worked out in the other section and with less observations per acre.

Transparent overlays were used with aerial photographs to record the location of observation sites. The sites were numbered consecutively and notes were taken on texture, color, depth to drainage mottles, coarse fragments, artifacts, soil structure, depth of fill, other special features and the series or taxonomic unit that the observation represented. Also the notes contained estimates of the type and extent of inclusions within different mapping units. Types of inclusions were small depressions with more poorly drained soil, mounds, soil in close proximity to sidewalks, and roads and buildings too small to show on the maps. During the detailed survey any new

kinds of soil features not provided for in the legend were noted and, if necessary, the legend and maps were corrected accordingly.

From the field notes, descriptions of the mapping units were prepared. The final product was a descriptive soil legend and a detailed soil map.

Results

The examination of existing information and the description of several pits revealed that the soils were developed in (1) river dredgings, containing silty and sandy materials deposited approximately 60 to 90 years ago (1, 5, 6, 9) with low contents of coarse fragments and artifacts, and/or (2) miscellaneous fill, generally less than 30 years old and consisting of a heterogenous mixture of materials with high contents of coarse fragments and artifacts. The soils in dredgings generally had prismatic subsoil structure and mottling patterns from which drainage classes could be inferred. The soils in miscellaneous fill had variable color patterns and textures that reflected the variable parent material. Descriptions and laboratory data for selected pedons are given in the District of Columbia Soil Survey Report (10, pp. 73-74).

From observations of auger holes and additional pits, criteria for the consistent recognition of miscellaneous fill material in the study area were developed. The presence of artifacts found deeper than an Ap horizon or 18 cm (7 inches) was considered diagonstic. Associated criteria such as variegated color patterns, wide range of particle sizes and shapes occurring together, pockets and strata of contrasting material, relatively abrupt horizon boundaries between "lithologically" different materials and irregular organic matter distribution with depth were used as supporting evidence in combination with the presence of artifacts.

Also from the pits, it was found that most horizons, in both the river dredging and miscellaneous fill soils, could be easily observed and traced around the sides of excavations. Horizon thickness and color patterns, distinctness of boundaries and horizon sequences were generally uniform within most excavations. The excavations were approximately one meter square to a depth of 1.5 meters and represented the minimum, three dimensional sampling unit known as a pedon. Certain properties, such as percent coarse fragments, amounts of artifacts, and texture showed considerable variability even within horizons of given pedons. To reduce sampling error for estimates of these more variable properties composite samples were taken from throughout the extent of each horizon around all sides of the excavation (pedon).

Transects made during the reconnaissance survey indicated that drainage class differences in the soils in dredgings were associated with relief. The soils developed in river dredgings so closely resembled natural soils in recent alluvium mapped along the Potomac that it was decided to place these into existing soil series (Table 1).

The soils developed in miscellaneous fills were divided into two kinds of units. The first kind consisted of shallow (<50 cm) fill over the soil series used for underlying dredgings (i.e., Newark fill phase). The actual mapping of these shallow fills proved to be difficult and time consuming and the field notes indicated considerable inclusions (i.e., 50%). The second kind was deep fill (>50 cm). These deeper fill soils were considered to be too variable to map at the series level and were considered to be Entisol-Inceptisol complexes. Strict taxonomic classification of many of these soils places them into great groups of Entisols (Udifluvents and Udorthents) if no cambic horizon is recognized or Inceptisols (Dystrochrepts and Eutrochrepts) if a cambic is recognized. No present taxonomic class

satisfactorily separates these soils from soils not highly influenced by man. A separation would be useful from a genetic, as well as from a management, viewpoint. In the District of Columbia soil survey (10) the mapping units of Entisol-Inceptisol complexes were correlated as Udorthents. This is perhaps the "best fit" for soil survey interpretations, but appears taxonomically wrong for most pedons.

Transects and mapping at a higher level of intensity in East and West Potomac Parks, on the Washington Monument grounds and/or parts of the Mall indicated that man-made topographic differences and roads could be used to aid in drawing certain boundaries between soils developed in miscellaneous fills. However, the use of these soil-landscape relationships on Columbia Island, where fewer observations per unit area were employed, resulted in at least one case of improper naming and delineation. In this case, the soil-landscape relationship was used to locate the boundary. Additional observations used to check the boundary indicated a proper designation, however, random sampling in an additional study to be reported later indicated a different mapping unit should have been used to designate the delineation or that the boundary was improperly located.

Various spot symbols were proposed for the study area at the outset of the mapping study. Field testing to evaluate the consistent and accurate use of these symbols eliminated all except the following; (1) wet spots, (2) severely eroded spots, (3) escarpments other than bedrock, and (4) short steep slopes.

An example of the detailed map is given in Fig. 3. The silty river dredging soils were found primarily on flood plain and terrace positions in East and West Potomac Park. The poorly drained Melvin soils were found almost exclusively in East Potomac Park, occurring at elevations below

3m (10 ft.). The somewhat poorly to moderately well drained Newark and Lindside soils were found in East and West Potomac Park and on Columbia Island. These soils occurred generally at elevations from 3 m (10 ft.) to 6 m (20 ft.).

The sandy river dredging soils were found on all landscape positions. The well drained Ochlockonee soil occurred on Columbia Island exclusively, at elevations ranging from just under 3 m (10 ft.) to slightly over 6 m (20 ft.). The poorly drained Bibb soils also occurred exclusively on Columbia Island, but at elevations under 3 m (10 ft.). The moderately well drained Iuka soils occurred in East and West Potomac Park, mapped with Newark silt loam, in complex units. The elevations ranged from approximately 1 m (3 ft.) to slightly over 3 m (10 ft.).

The shallow fill soils were mapped over silty dredgings in East Potomac Park (Newark fill phase) and over sandy dredgings, mainly in West Potomac Park and on Columbia Island (Iuka, Ochlockonee and Bibb fill phase). These soils occurred over a range of elevations from 1 m (3 ft.) near the margins with water to near 6 m (20 ft.) on upland positions.

Complex mapping units were used in East and West Potomac Park and on Columbia Island where various series of silty and sandy river dredging soils occurred together. These soils were so intimately associated that they could not be separated by boundaries at the scale of mapping that was used.

The deep miscellaneous fill soils, mapped as Entisol-Inceptisol complexes but correlated as Udorthents in the D.C. survey (10) occurred mainly on upland positions in/on West Potomac Park, Washington Monument Grounds, The Mall and Columbia Island. They also occurred on flood plain and terrace positions, however, not to as large an extent. They ranged in elevations from 1 m (3 ft.) to slightly over 9 meters (30 ft) and generally would be considered well drained unless located in local depressions or seepage areas.

Summary

Existing records, both historical and recent, were used to help delineate and date fill deposits. Criteria to consistently recognize fill deposits were developed with the presence of artifacts at depth being diagnostic.

The soils developed in river dredgings were so similar to existing soils in recent alluvium mapped along the Potomac that they were placed into current soil series (Newark, Linside, Melvin, Ochlockonee, Iuka, Bibb) concepts of soils in two depths of miscellaneous fill deposits were developed. One is that of shallow fill, more than 18 cm, but less than or equal to 50 cm over existing soil series (e.g., Newark fill phase). The mapping of these kinds of soils proved difficult and time consuming and it was estimated from field notes that up to 50% inclusion occurred. The other concept is that of deeper fill (>50 cm). These soils were mapped at a higher category level (great group) and from field note estimates had less inclusions. They were difficult, however, to examine with an auger because of high contents of coarse fragments and high bulk densities.

Evaluation of the mapping and studies illustrating the variability of the kinds of soils recognized will be covered in subsequent reports.

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Table 1. Soil Mapping Legend Key[1/]

I. Textures within 1 meter dominantly sands, loamy sands and sandy loams[2/]

1. Fill less than 18 cm (or depth of Ap)
   2. Low chroma (≤2) matrix - - Bibb sandy loam (Bg)
   2. Low chroma (≤2) mottles within 50 cm - - Iuka sandy loam (Ik)
   2. Low chroma mottles deeper than 50 cm - - Ochlockonee sandy loam (Oc)

1. Fill greater than 18 cm but less than or equal to 50 cm
   2. Low chroma (≤2) matrix - - Bibb fill phase (Bh)
   2. Low chroma (≤2) mottles within 50 cm - - Iuka fill phase (Im)
   2. Low chroma (≤2) mottles deeper than 50 cm - - Ochlockonee fill phase (Ok)

1. Fill greater than 50 cm - - Entisol-Inceptisol Complex (Udorthents) (U1)

I. Textures within 1 meter dominantly silt loams, loams and sandy loams[3/]

1. Fill less than 18 cm (or depth of Ap)
   2. Low chroma (≤2) matrix - - Melvin silt loam (Mp)
   2. Low chroma (≤2) mottles within 60 cm - - Newark silt loam (Nv)
   2. Low chroma (≤2) mottles deeper than 60 cm - - Lindside silt loam (Ld)

1. Fill greater than 18 cm but less than or equal to 50 cm
   2. Low chroma (≤2) matrix - - Melvin fill phase (Mw)
   2. Low chroma (≤2) mottles within 60 cm - - Newark fill phase (Nw)
   2. Low chroma (≤2) mottles deeper than 60 cm - - Lindside fill phase (Lw)

1. Fill greater than 50 cm - - Entisol-Inceptisol Complex (Udorthents) (U1)

1/ The soils encountered were mapped on floodplain, terrace and upland positions.

2/ With variable thickness of miscellaneous fill over coarse-loamy to sandy dredgings.

3/ With variable thickness of miscellaneous fill over fine-loamy to silty dredgings.

Figure 1: Map of study area.

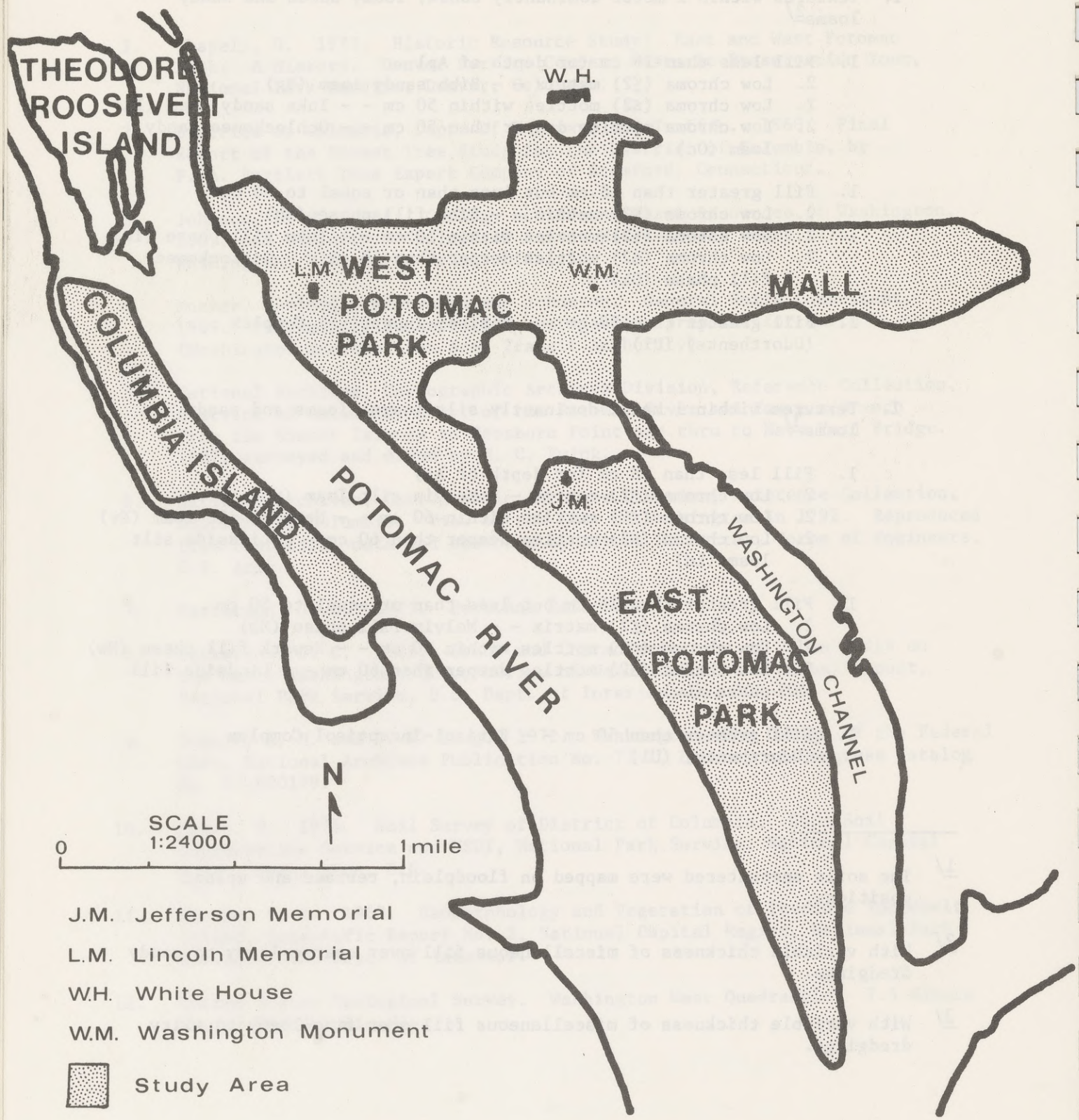

Figure 2: General soil map of study area.

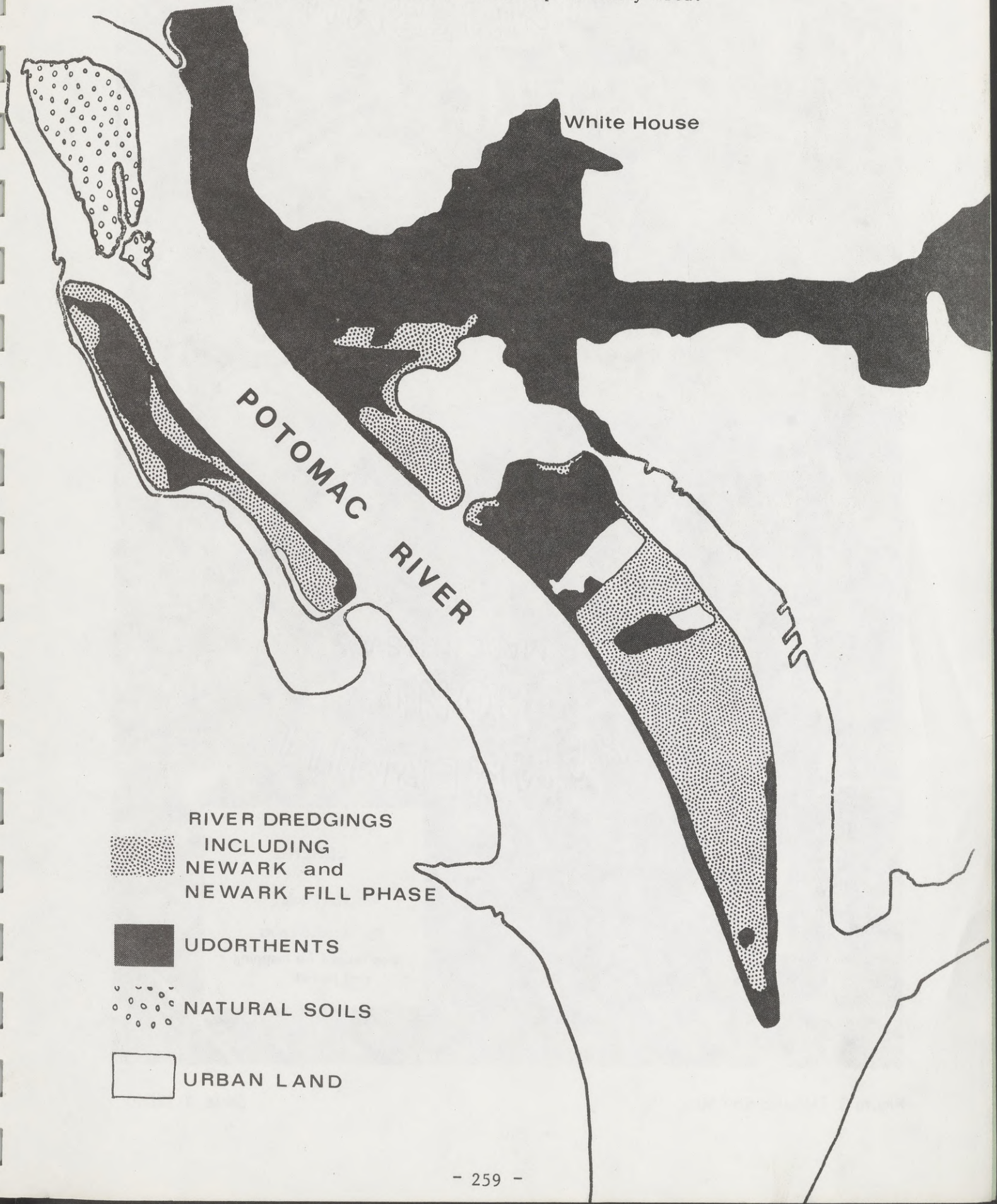

Figure 3 Detailed Soil Map

Scale 1:12000